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Ballistic Trauma in Finland

An Epidemiologic and Clinical Study of Firearm and Explosion Injuries

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Contents

Abstract

National occurrence and nature of civilian firearm and explosion injuries (ballistic trauma) were described for the period from 1985 to 2004, with a special interest in firearm wounds of the extremities. The present study was population based, using data derived from the Finnish National Hospital Discharge Register and the relevant registers and archives of Statistics Finland. Epidemiologic methods were used in six and clinical analyses in four of the seven papers. In these clinical studies, the original hospital records and death certificates were critically analyzed.

Civilian firearm-related injuries have decreased during the almost 20-year study period. The total number of hospitalizations for firearm-related injuries declined from 254 in 1990 to 133 in 2003 (5.1 per 100 000 person-years in 1990 to 2.6 per 100 000 person-years in 2003), which was largely attributable to a simultaneous decrease in unintentional injuries (138 in 1990 to 45 in 2003). However, the incidence of intentional injuries remained unaltered over the study period (98 in 1990 to 78 in 2003). One of strongest risk factors for firearm injuries in Finland are suicidal attempts, a phenomenon characteristic of the country.

The occurrence of civilian, explosion-related injuries was on average of 100 cases per year (2.0 cases per 100 000 person-years) in the country in the 1990s. The number of civilian, fatal explosion-related injuries has slightly increased from 1985 to 2004. However, in practice, these injuries occur only sporadically in the country and, epidemiologically, they represent a minor problem.

The main finding of the present study was that, contrary to many other countries, both undeveloped and developed, the trend of firearm injuries has declined in Finland, especially regarding unintentional firearm injuries. Another important finding was that the relationship of intentional injuries with alcohol and illegal drug and substance use is remarkable. This is a notable challenge for the future, because alcohol legislation has recently become more liberal in the country and the consequences of the lower taxation on alcohol consumption are not yet known. The third finding was that management of severe extremital gunshot injuries presented unexpected challenges in trauma surgery. Some complications associated with gunshot fractures, as well as the need for primary amputation or vascular reoperation in severe vascular injuries may be noteworthy. However, the policy of treatment is a difficult issue, because injuries studied here are rarities for trauma centers in the country. The low population density and relatively large geographic area of Finland do not favor high volume, centralized trauma management systems, which is reflected in the material presented here.

This study demonstrates that the prevalence of firearm-related, as well as rare, explosion-related, injuries is stable in Finland. National characteristics exist, but, at the turn of the millennium, the incidence of unintentional and intentional firearm and explosion injuries has been controlled by the society to an acceptable degree.

List of Original Publications

I Böstman O, Marttinen E, Mäkitie I, Tikka S: Firearm injuries in Finland 1985–1989. Ann Chir Gyn, 1993;82:47–49.

II Mattila V, Mäkitie I, Pihlajamäki H: Trends in hospitalization for firearm-related injury in Finland in 1990–2003. J Trauma 2006, in press.

III Mäkitie I, Pihlajamäki H: Fatal firearm injuries in Finland. A nationwide survey. Scand J Surg 2002;91:328–331.

IV Tikka S, Böstman O, Marttinen E, Mäkitie I: A retrospective analysis of 37 civilian gunshot fractures. J Trauma 1996;40:(Suppl):212–216.

V Mäkitie I, Mattila V, Pihlajamäki H: Severe vascular gunshot injuries of the extremities: a ten-year nation-wide analysis from Finland. Scand J Surg 2006;95: in press.

VI Mäkitie I, Paloneva H, Tikka S: Explosion injuries in Finland. Ann Chir Gyn 1997;86:209–213.

VII Mäkitie I, Pihlajamäki H: Fatal explosion injuries in Finland: a twenty-year nationwide survey. Scand J Surg 2006;95: in press.

The publishers have kindly granted permission to reprint the original articles.

Abbreviations

AAT	Acute Acoustic Trauma
CDS	Cause-of-Death Statistics
CI	Confidence interval
DSFDF	Defense Staff of the Finnish Defense Forces
FDF	Finnish Defense Forces
ICD	International Classification of Diseases
NHDR	National Hospital Discharge Register
OCDS	Official Cause of Deaths
SPSS	Statistical Package for Social Sciences
STAKES	National Research and Development Center for Welfare and Health
WHO	World Health Organization

Introduction

Physical trauma in its many forms is a major cause of death and disability both in developed and developing countries (Leppäniemi 2004). Injuries have been one of the most serious public health problems facing developed societies (Baker 1984). The occurrence of injuries is largely determined by characteristics of the environment, particularly environmental modifications by various organizations (Baker 1984).

Weapons have been invented, refined and adapted over the course of human history (Bowyer et al. 1997). Ballistics (Gr. *ballein* to throw) is the scientific study of the motion of projectiles in flight. Most of today's antipersonnel weapons cause ballistic traumas, and their origins can be traced back over thousands of years. The most typical ballistic traumas are those caused by firearms and explosions (blasts). Ballistic trauma is at present an international concern for numerous agencies, both civilian and military (Ryan 1997).

It is estimated that millions of people around the world are hospitalized each year due to non-fatal firearm-related injury (WHO 2001). Firearms have claimed approximately 200 000 lives per year in terms of non-combat related homicide, suicide and accidental injuries (UN 1997). In recent armed conflicts, small arms (definition on page 14), light weapons, and firearms have killed an estimated 300 000 people per year on average, and were the only weapons used in 46 major conflicts fought between 1990 and 1998 (ICRC 1999). In Europe, firearm-related injuries have traditionally been regarded as a minor problem as they account for only a small percentage of the total number of trauma cases seen in emergency departments (Numez et al. 2000, Di Bartolomeo et al. 2004, Leppäniemi et al 1996). On the other hand, injuries caused by firearms are one of the major causes of mortality and morbidity in the United States (Annest et al. 1995, Schwarz et al. 1994, Sing et al. 1997).

The frequency of explosion (blast) injuries treated by civilian and military surgeons is on the rise mainly due to terrorist activity. The type and extent of injury caused by explosion vary, depending on the type of munition employed and the environment of occurrence (Mellor et al. 1997).

Despite the extent and consequences of these injuries worldwide, a systematic collection of local data on firearm or explosion morbidity and mortality to help guide policy development is lacking (WHO 2001), and most of the studies published concerning firearm-related injuries originate from the United States (Annest et al. 1995, Cheng et al. 2001, Cherry et al. 1998). However, injury rates in the United States are not comparable to Europe (Numez et al. 2000, Wright 1997, Di Bartolomeo et al. 2004). The long history of political, cultural, religious, ethnic, linguistic, and economic rivalry between the larger European powers has prevented any uniformly acceptable working principle from emerging in any field of life, including medicine (Fingerhut et al. 2002).

In the Scandinavian countries, firearm injuries have not been considered as a major problem due to the restrictive legislation regulating civilian possession and use of firearms in these societies. However, it has been shown that firearm-related mortality in Finland is one of the highest in Europe (Krug et al. 2002). Despite these facts, there has been a lack of population based epidemiologic studies on firearm-related injury hospitalization in Europe.

In Finland, the first epidemiologic study, published in 1992, on the occurrence of firearm injuries covered the years 1985–1989 (Böstman et al. 1992). The results indicated that injuries of this kind, although a minor medical problem in the country, cannot be ignored (Böstman et al. 1992). However, no larger studies using population based samples of ballistic traumas have previously been published in Finland.

An epidemiologic study conducted in Finland can furnish us with accurate information on the incidence, nature and severity of firearm-related, as well explosion-related, injuries owing to the accuracy and high coverage of the National Hospital Discharge Register in Finland, the oldest established nationwide discharge register in the world. The mortality from firearm injuries can also be adequately studied as the Finnish Cause-of-Death Statistics have proven to be accurate and complete (Keskitalo and Aro 1991, Salmela and Koistinen 1987).

There is evidence that a firearm-related injury predicts a significant long-term decline in physical and mental health in the future (Greenspan and Kellerman 2002), as well as crimes and violent death (Ponzer et al. 1995, Ponzer et al. 1998). Injuries studied here have been categorized as low and high energy wounds. Moreover, they can be divided into civilian and war injuries. The ensuing conclusions cannot be understood dogmatically and should in many cases be evaluated according to the environment from which they derive. The reason for intentional or unintentional shooting is not always known.

If the incidence does not significantly change in one country when comparing to other countries, the phenomenon offers interesting challenges to examine the backgrounds and prevention strategies for firearm injuries between the different countries. In general terms, gun-related violence has been of lesser importance in Finland. While the injuries are not a great problem in the country, gun-related suicides have been characteristic of the rural areas (Mäkitie et al. 1996). Unfortunately, many of these suicides obviously do not reach surgical interventions (Mäkitie 2001).

However uncommon gun and explosive-related injuries are, they usually catch the public interest. Moreover, it is worth noticing that firearm injuries have already been investigated in the country in terms of experimental surgery and law enforcement (Tikka 1989, Jussila 2005). The epidemiologically and clinically based study presented here gives additional information on a national scale for the injuries examined.

Studies of explosion injuries from Finland are lacking. However, in view of the internationally expanding trend in the use of explosive devices among terrorist organizations, there is an increasing possibility of blast injuries presenting to civilian surgeons.

Epidemiologic studies are worthless without presentation of strategies and methods offering means to decrease the occurrence of the studied diseases or traumas. Research should underline the notion that reducing the occurrence of shooting incidents is a demanding task for the whole society. However, practical solutions in ballistic-related injury epidemiology have hardly been published in Europe, but some literature is available from the United States (e.g. Karlson et al. 1997). In a highly developed and politically stabile country like Finland, one might expect to find methods to reduce injuries studied here.

The small population density and the relatively large geographical area of Finland do not favor high volume, centralized trauma management systems. However, the gross national product per capita was 36 360 US Dollars in 2003, and one of the highest in the world. Facilities for high-quality trauma care should be available, and expectations for good outcomes in any field of trauma surgery should be met.

The main focus of this study is to report the occurrence and nature of firearm- and explosion-injuries leading to hospitalization in Finland, with the nature of firearm-related injuries reaching medical treatment as one of the key issues. Moreover, reporting fatal injuries provides complementary information, elaborating the backgrounds of the most severe injuries.

There was also a special interest to investigate severe firearm injuries of the extremities. Clinical studies of the consequences of severe gunshot injuries, like the extremital injuries here, provide useful information for trauma education and for surgeons operating in trauma departments. It should be noted that truncal gunshot wounds have already been studied to a substantial degree in the country (Leppäniemi et al. 1996, Streng et al. 2001). The results of the present study may contribute to military medicine, since the majority of war wounds occur in the extremities.

The final aim of the study was to present practical strategies and methods for the control and reduction of ballistic trauma occurrence in the country in terms of recommendations that have not yet been widely published.

Review of the Literature

1. Definition of Ballistic Trauma

1.1 Definition of the terms ballistics, ballistic, and wound ballistics

The terms ballistics (n.) and ballistic (a.) derive from the Greek verb ballein ($\beta\alpha\lambda\lambda\epsilon\iota\nu$) meaning to throw. Ballistics is the study of projectile motion. Ballistic studies can be divided into three main groups: interior, exterior and terminal ballistics. Interior ballistics deals with the behavior of the bullet/projectile from the moment it is fired to the moment it leaves the firearm's muzzle. Exterior ballistics concerns the flight of the projectile after discharge, from the muzzle to the target. Terminal ballistics (e.g. wound ballistics) describes what happens when the target is hit.

The Swiss surgeon Emile Theodor Kocher (1841–1917) is regarded as the founder of wound ballistics as an experimental science (Bellamy and Zajtchuk 1991). However, the term wound ballistics, introduced by Callender and French in 1935, pertains to the scientific study of the velocity and direction of flying projectiles (e.g. bullets and fragments) in respect to the wounds and injuries they inflict (Callender and French 1935). The term ballistic, in turn, pertains to the study of the dynamics of projectiles.

1.2 Patterns of injuries by mechanism and intent in general

Injury epidemiologists should have at least a rudimentary understanding of the energy involved in shooting or firearm use and of the tolerance of human beings to exposure of that energy. However, it is well known that both the exposure to the energy and the consequences of that exposure are greatly influenced by a variety of factors, some within and others beyond our control (Robertson 1998).

These concepts were first articulated in the late 1960s by William Haddon Jr, who proposed a matrix approach for delineating the risk factors associated with the occurrence and severity of injury (Table 1) (Haddon Jr 1968). His phase-factor matrix retains the classic epidemiologic framework of host, agent, and environment, yet emphasizes the dynamic process of injury causation. The time sequence is divided into three phases: pre-event, event, and post-event. Factors in the pre-event phase determine whether the event will occur; factors in the event phase determine whether an injury will occur; and factors in the post-event phase influence the outcome from, or consequenses of, the injury. These phases interact with the three sets of factors encountered in each phase, namely, host or human factors (including both biologic and behavioral factors), factors associated with the agent or vehicle of energy transfer such as car or gun, and the environmental factors (MacKenzie and Fowler 2004).

Table 1. The Haddon phase-factor matrix by Haddon (1968).

		Factors			
				Environment	
		Host (human)	Agent (vehicle)	Physical	Social
PHASES	Pre-event	Driver age, gender, driving experience, drug or alcohol use, vision, fatigue, frequency of travel, risk-taking behavior	Vehicle speed, brakes, tires, road-holding ability, visibility (e.g., daytime running lights)	Road design and traffic flow, road conditions, weather, traffic density, traffic control (lights, signals), visibility	Speed restrictions, impaired driving laws, licensing restrictions, road rage, seatbelt and child restraint laws
	Event	Age, pre-existing conditions (e.g., osteoporosis), restraint use	Vehicle speed, size, crash-worthiness, type of seatbelts, airbag, interior surface hazards	Guardrails, median dividers, break-away poles, roadside hazards	Enforcement of speed limits
	Post-event	Age, comorbidities	Integrity of fuel system	Distance from emergency medical care, obstacles to extrication	EMS planning and delivery, bystander control, quality of trauma care, rehabilitation, compensation practices.

EMS, emergency medical services

Injuries are categorized by their mechanism, intent, and site of injury. Intent of injury is classified as either unintentional (often referred to as accidental), intentional (intentionally inflicted by someone on someone else or on himself or herself), or undetermined. Injuries resulting from legal interventions and operations of war are typically classified separately as an "other intent" category. Intentional injuries are further classified as assaults or homicides versus self-inflicted injuries or suicides.

1.3 Definition of a firearm

A firearm is a launching system for bullets. Traditionally, they have been divided into categories of handguns, rifles, and shotguns, and their bullets respectively into low and high energy projectiles. Even if this division could decades ago be somehow justified, today it has little to do with reality, because the division between handguns and rifles and their separate ammunition types has long been obscure (Jussila 2005).

The term "small arm" can be described as a handgun. Small arm is not easily defined, but usually includes weapons that can be carried by hand. This weapon class encompasses such items as pistols and revolvers, rifles and assault rifles, and moreover, different kinds of military small arms such as hand grenades, machine guns, light mortars, and light anti-tank weapons like grenade launchers and recoilles rifles. It has been recognized that most small-arms engagements are within a range of 200 m, so rapidity and reliability of fire assume greater importance than long range accuracy (Bowyer et al. 1997).

A shotgun is no longer a device for launching a handful of round pellets (Jussila 2005). It is capable of firing not only pellets but solid projectiles ("slugs"), sabotted bullets, tear gas, kinetic impact projectiles that act as remote batons, breaching ammunitation for forcing an entry, and so forth (Jussila 2005).

Bullets are often categorized with descriptive attributes like military, civilian, police, high-velocity and low-velocity. Seen from the perspective of ballistics, these categories mean nowadays very little and can lead to false conclusions and generalizations (Jussila 2005).

1.4 Firearms in different societies

No one really knows how many weapons are in circulation among the general population of most countries (Renner 1997). International Physicians for the Prevention of Nuclear War Organization has estimated that more than 500 million military-style small arms circulate in global markets, along with an equivalent number of civilian-type fireams, and the demand is increasing (IPPNW 2002). The first international effort to gain some insight into the problem was the study by the U.N. Commission on Crime Prevention and Criminal Justice (Renner 1997). This study conducted a survey of the member states with the aim to collect and compare data on the manufacture, trade, and private possession of firearms, on national regulations for firearms, and on homicides, suicides, and accidents involving firearms (UN 1997).

The combined official figure of WHO's study produced a figure of 34 million firearms in private possession for the 35 countries that provided data, which probably represents little more than the tip of the arsenal iceberg (Renner 1997).

Russia, for example, reported a figure of 3,6 million, but they are generally thought to have a huge number of illegal guns in circulation, with the black market being fed through profuse leaks from the national military arsenal (Renner 1997).

In Canada, as another example, the number of legitimate owners is unknown; instead of the 7 million figure submitted to the U.N., estimates of as many as 21–25 million firearms in private possession have been made (Renner 1997).

The United States is, without a doubt, a country with one of the largest private firearm arsenals, and very likely the world leader in this aspect. There are a quarter of a million federally licensed firearm dealers in the country. Estimates of private firearm ownerships in the United States run from 192 million to 230 million according to the U.S. National Rifle Association (Renner 1997).

1.5 Firearms in Finland

1.5.1 Demographic background

Finland is a country with a population of about 5 million, the major ethnic groups being Finns (93%) and Swedes (6%) (Official Statistics 2003). The gross national product per capita in Finland was 36 360 US Dollars in 2003. It is one of the most sparsely populated countries in Europe, with 60% of the people living in towns and cities (Official Statistics 2003). Cities are located mainly Southern Finland, while Northern Finland is rural. Lawful firearms are owned for the purpose of hunting, target shooting, and collection. Manufacture, import, trade, acquisition and possession of firearms require a permit, granted by the local police departments.

Finland is divided into 5 geographically separate university regions (north with 722 605, southwest with 685 063, west with 1 188 900, east with 857 374, and south with 1 726 096 inhabitants) (Official Statistics 2003) (Population data from Statistics Finland, 2002), and each of them has one university hospital (Figure 1). Further, less severe injuries are treated at 16 central hospitals and 33 district hospitals. Altogether, around 80 000 injury hospitalizations occur in the Finnish hospitals per year (Official Statistics 2003).

1.5.2 Small arms and permissions in Finland

There are approximately 1,7 million firearms in Finland (shotguns 30%, rifles 25%, rifles .22 cal 13%, handguns 19%, others 13%), and the percentage of households with firearms is 50% (Aselakityöryhmä, Vessari et al. 2001). In the year 1984, the number of legal guns was 1 712 600 (guns owned by the Finnish Defense Forces excluded), and by 2001 the number was estimated to have risen to around 1,8 million (Vessari et al. 2001).

In the year 2000, 56 796 new firearm permits were granted: 18 473 for shotgun, 23 073 for rifle, 1622 for combination rifle, and 9595 for pistol or revolver. At that time, a gas spray was already comparable to a firearm and the number of these licences was 2980. Altogether 318 permits to manufacture a firearm were given: 21 for shotgun, 176 for rifle, 38 for pistol or revolver (Vessari et al. 2001).

Also in 2000, 1060 applications for various firearm-related permits were declined, about 90% being applications for acquisition of a firearm. The most common reasons for declination were lack of justified reason to acquire a firearm (about 50%) and behavioral reasons (about 25%). In 43 cases (about 4%), the health of the applicant was the reason for declining (Vessari et al. 2001). On a yearly basis, 700–800 firearm permits are cancelled, mostly due to violent behavior of the firearm owner (Paanila 2001).

Also the number of illegal firearms is relatively high: according to the estimate given by the Ministry of Interior, the number of unregistered guns was 100 000–200 000 at the turn of the millenium (Vessari et al. 2001).

1.6 Definition of a firearm injury

The term "wound ballistics" comprises studies of the physiology and medical effects of projectile weapons. Three major actors govern the severity and outcome of a ballistic wound, namely, the weapon used, the setting in which it is used, and the quality and timing of medical management. These factors have all varied throughout the history of weapons, wars, and the evolution of medicine (Bowyer et al 1997).

University Region	Population	Gross National Product / Capita (U.S. $)
Oulu (OUR)	722605	29 800
Kuopio (KUR)	857374	27 300
Tampere (TaUR)	1188900	29 800
Turku (TuUR)	685063	33 500
Helsinki (HUR)	1726096	47 300

Figure 1. Finnish university hospital regions and their population and gross national product per capita in US $ in 2002.

The wounding capacity of bullets has been considered to mainly depend on the mass and velocity of the projectile**.** The following three hypotheses for the factors determining the degree of wounding have been proposed: 1) kinetic energy, 2) power, and 3) momentum (Tikka 1989).

The kinetic energy theory is most widely accepted. According to this theory, the wounding power depends on the amount of energy transferred to tissues, thus emphasizing the importance of velocity at impact. However, neither the momentum nor the rate at which the energy was released, power, could be correlated without a great deviation from any of the various events occurring in the missile wound. The factors involved in wound production are the shape, weight, and velocity of the bullet, the density and character of the tissue involved, and the direction and amount of the transmitted energy (Tikka 1989).

The amount of energy transfer is proportional to the retardation force acting on the projectile in tissues of different densities. However, the common term “high-velocity effects”, widely used because of the increase of muzzle velocity in small caliber arms projectiles, is not quite appropriate. The term “high energy transfer” was suggested in 1983 by Jansson, who presented that factors such as rapid tumbling, deformation and break-up are more decisive than velocity (Bowyer et al. 1997). In a “low energy transfer mechanism”, a typical crushing and laceration effect is caused by the projectile itself when traveling through the tissues. The amount of energy transferred into tissues is very low and damage is limited to an area in direct contact with the projectile. Only a small wound cavity is created with little damage to its surroundings (Harvey et al. 1962).

These wounds are characterized by an injury to the structure directly in the path of the missile, and caused by a simple cutting or crushing action. Many handgun bullets produce wounds of this character. Severity and outcome will be determined by the structures encountered, rather than the physical behavior of the missile. The author of the present study finds it intriguing that terms like ‘firearm injury’ or ‘gunshot injury’ have gained such wide acceptance, when terms like ‘bullet injury’ or ‘bullet wound’ would be more appropriate and accurate.

In the high energy transfer mechanism, a high energy projectile penetrates the tissue while pressure waves radiate out from the trajectory, causing mechanical dislocation, derangement, and possible heating of the tissues. A vapor-filled “explosive” or temporary cavity will immediately form behind the projectile. This expanding cavity causes pressure changes and tearing in the surrounding tissues. Following its initial expansion, the cavity will collapse, but may then re-expand and collapse again several times during the pulsating temporary cavity, which might extend to about 30 times the diameter of the projectile (Harvey et al. 1962). Positive and negative pressures alternate in the wound cavity. The pulsation combined with negative pressure are sucking foreign material and infectious agents into the wound channel through both apertures. The high and rapid energy transfer causes tissue damage to extend considerably outside the visible permanent cavity. Ruptures in small blood vessels and capillaries induce large extravasation (Harvey et al. 1962). The phenomenon is a splashing, destroyed tissue hurling outward and causing loss of material at points of entrance and exit of a missile. The retentive forces of different tissues must be considered (Tikka 1989)

Fackler has concluded that the sole wounding mechanisms are tissue crush and tissue stretch. Tissue crush causes the permanent cavity and tissue stretch is responsible for the temporary cavity. His concept is that a cavitation is no more than a transient displacement of tissue, a tissue stretching. Fackler's wound profiles illustrate the amount, type, and location of tissue disruption, projectile mass, velocity construction, as well as projectile deformation and projectile fragmentation pattern. His opinion was that the major role in tissue is played by bullet fragmentation or deformation and not by its high-velocity and temporary cavitation effects (Fackler 1988).

The potential for clinically significant injury increases in wounds of this character. High levels of energy transfer involve structures radial to and remote from the permanent wound track owing to the formation of a temporary cavity or disruption of the missile. Mechanical distortion will result in injury, the extent of which will depend on the nature and density of structures involved. Finally, contamination is likely to be widespread and may not be obvious at wound track exploration.

Generalizations about ballistic injuries contain numerous uncertainties, including the large number of variables that complicate the discourse of a typical ballistic wound. The nature of the weapon system involved, behavior of different tissues and body systems, injury environment and management, all exert their influence, defying any attempt to generalize over either the biophysiologic or pathophysiologic events that follow (Ryan and Rich 1997).

From the pathophysiologic point of view, there can be few presumptions when faced with a victim of a ballistic trauma. Knowledge of the weapon or wounding missile occasionally offers insight into the pathophysiologic sequelae, but little should be assumed with regard to wound severity. The wound should be approached with an open mind and with a knowlegde of the events that may ensue. Clinical conclusions of the outcome should be made only following surgical exploration and not before (Ryan and Rich 1997). The extent of energy transfer and wound severity will usually be obvious during exploration and surgeons have been best advised to heed the old adage: "Treat the wound, not the weapon" (Ryan and Rich1997).

The future is likely to bring changes to the military armaments, with the development of directed energy or blast weapons (Walker 1990). This may eventually have an effect on the relative prevalence of ballistic wounds in a high-intensity conflict, involving large established forces (Ryan and Rich 1997). However, firearms and fragmenting weapons will continue to be used well into this millenium in armies, paramilitary groups, as well as the civilian life, and, consequently, ballistic trauma will continue to present a problem to military and civilian surgeons alike (Ryan and Rich 1997). The nature and mechanism of military gunshot wounds have also been experimentally studied in many European countries (Janson 1983, Scepanovic et al. 1982, Sellier et al. 1994, Tikka 1989).

1.7 Definition of an explosion

The explosion of a conventional bomb generates a blast wave that spreads out from a point source. The blast wave consists of two parts, a shock wave of high pressure followed closely by a blast wind, or air in motion. The physics of blast waves is nonlinear and complex. In general, damage produced by blast waves decreases exponentially with distance from the point source of the blast (Collis 2001).

Chemical explosives (e.g gun powder, trinitrotuloene) are substances which on detonation are transformed into large volumes of hot gases within a fraction of a second. The lightning-like expansion of these gases compresses the surrounding air and causes a blast wave (shock wave) which moves away from the center of explosion as a rapidly expanding sphere at velocities of over 3000 meters per second (Figure 2).

When explosions occur indoors, standing waves and enhanced differences in pressure occur because of the additional effects of reflections or reverberations from walls and rigid objects. As outward energy dissipates, a reversal of wind back toward the blast and underpressurization occurs. The resulting pressure effect damages human organs, particularly at air-fluid interfaces, and the wind propels fragments and people, causing penetrating or blunt injuries (DePalma et al. 2005).

Enhanced blast explosive devices, in contrast, can have more damaging effects. A primary blast from these devices disseminates the explosive and then triggers it to cause a secondary explosion. The high-pressure wave then radiates from a much larger area, prolonging the duration of the overpressurization phase and thus increasing the total energy transmitted by the explosion. Enhanced-blast devices constitute the cause of a greater proportion of primary blast injuries than do conventional devices (De Palma et al. 2005).

In confined spaces, such as buildings and busses, irregular high-pressure waves from either conventional or enhanced-blast devices cause unpredictable patterns of injury.

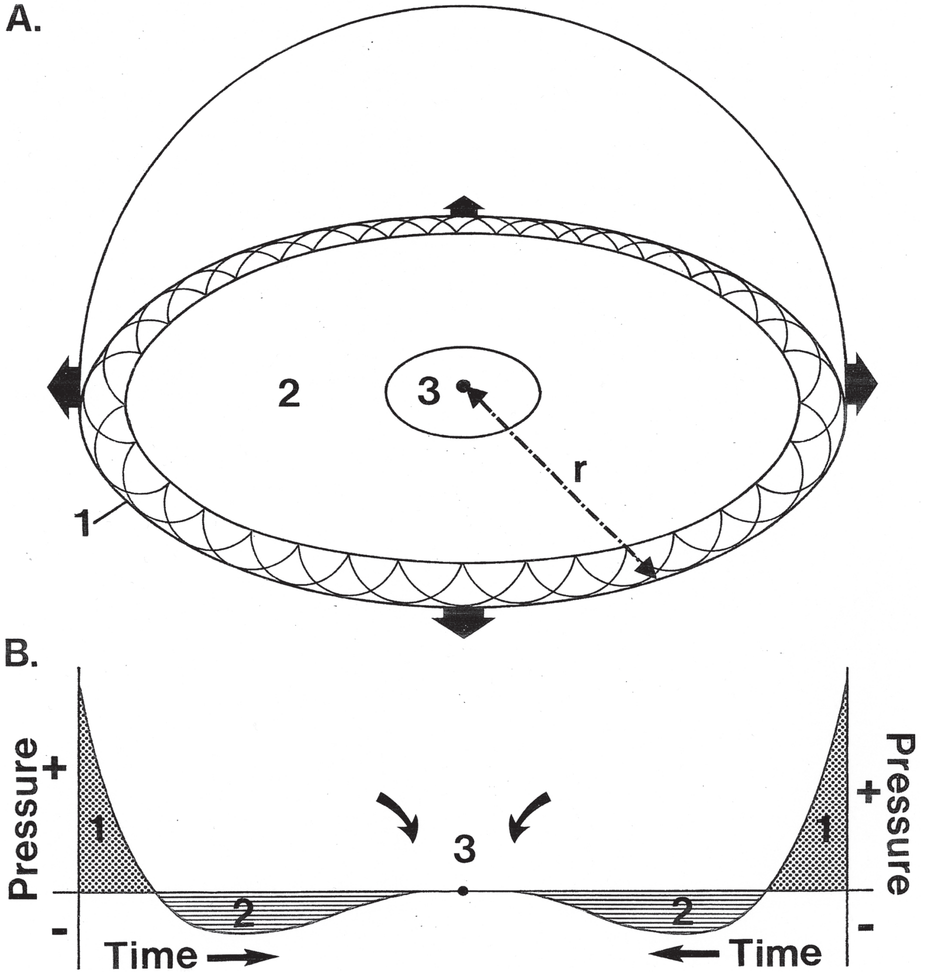

Figure 2. A. Composed of two phases, the blast wave advances spherically from the center of the explosion at initial velocities of over 3000 meters per second (>18000 km/h). The first, positive pressure phase (1) is followed by a negative pressure phase (2). The negative phase is followed by a mass movement of air, the blast wind (3) replacing the amount of air displaced by the explosion. The total surface area affected by an explosion can be calculated using the mathematical formula πr^2 with r (radius) representing the distance between the center of the explosion and its farthest away destructive and/or injuring effects.
B. The positive pressure phase (1) attains pressures of up 1000 atm decreasing gradually with time and distance to the speed of sound in air. The negative or suction phase (2) is weaker, but lasts up to ten times longer than the positive phase. The blast wind (3) advances at velocities of up to 700 km/h and causes mechanical injuries of all degrees of severity, including total disintegration of the human body. (©Research Institute of Military Medicine / Larni HM, Mäkitie I 2006.)

1.8 Definition of an explosion injury (blast injury)

The effects of blasts fall into the following four categories: primary (direct effects of pressure), secondary (effects of projectiles), tertiary (effects due to wind), and quaternary (burns, asphyxia, and exposure to toxic inhalants). The types of injuries caused by blasts depend on whether the blasts occur in open air or within buildings, and whether they cause the collapse of a building or other structure.

There are five general classifications for injury from explosions (Mellor et al. 1997):

1. *Primary injury* is caused directly by the blast wave and encompasses injury to air-containing organs such as the lung and bowel, and to solid viscera.
2. *Secondary injury* is caused by the impact of missiles from the explosive device or from other debris energized and propelled by the explosion. The classification includes penetrating and blunt impact injuries.
3. *Tertiary injury* results from displacement, either traumatic amputation caused by the blast or injuries resulting from displacement of the body as a whole.
4. *Quaternary injury or flash burns* result from the intense, brief thermal output of the explosion.
5. *Crush injury* may occur if the explosion is sufficient to cause collapse of a building.

In practice, survivable injuries from explosions are nearly always the result of secondary missiles accelerated by the explosion. There is a lethal zone around every explosion and, within this zone, survival of persons unprotected from the blast wave is not possible (Mellor et al. 1997).

Clinicians should consider the type of explosive device and its location when evaluating victims of terrorist attacks. Blast injuries should be suspected regardless of the distance between the patient and the blast center, and despite absence of injuries in persons located near the patient (Arnold et al. 2004).

2. Epidemiology of Firearm Injuries

2.1. Global background

As mentioned in the introduction, it has been estimated that millions of people around the world are hospitalized each year due to a non-fatal firearm-related injury (WHO 2001). Firearms have claimed approximately 200 000 lives per year in non-combat related homicides, suicides and accidental injuries (UN 1997). In recent armed conflicts, small arms, light weapons, and firearms have killed an estimated 300 000 people per year on average, and were the only weapons used in 46 major conflicts fought between 1990 and 1998 (ICRC 1999). By their design – small, portable, rugged, inexpensive, and deadly – small arms have evaded detection and brought extreme destruction to health and development around the world.

Gun-related injuries have often been studied by epidemiologists as if all guns and bullets were the same (Robertson 1998). Ballistic trauma is encountered in civilian medical practice, but an accurate picture of the epidemiology is difficult to draw. Criminal incidents involving firearms are certainly increasing, but the number of civilian deaths from firearms in England and Wales has shown little change over the past 20 years (Bowyer et al. 1997). The incidence and nature of violence are poorly reflected in police statistics and crime data (Bowyer et al. 1997). It has been suggested that accident and emergency departments of hospitals would provide better indicators, but epidemiologic studies are lacking (Shepherd et al. 1993). The concepts of epidemiology, used in concert with those from other disciplines, including medicine, sociology, behavioral sciences, and biomechanics, are critical to the development of effective interventions for reducing injuries and their adverse consequences (MacKenzie and Fowler 2004).

2.2 Epidemiology of fatal firearm injuries

Death rates from firearm injuries have been found to vary markedly throughout the industrialized world (Figure 3) (Krug et al. 1998). Medically, life-threatening firearm injuries present major challenges. Several factors determine the severity of a firearm injury and its outcome (Ryan et al. 1997). Important factors associated with firearm injury fatalities are the anatomic area of impact, the type of weapon and bullet used, the setting in which the injury is sustained, and the nature and timing of medical injury management.

In their 1998 report, Krug and colleagues examined firearm related deaths in the United States and 35 other high- and upper-middle income countries. They showed that the overall firearm mortality rates are five to six times higher in high-income and upper-middle-income countries in the Americas than in Europe (Krug et al. 1998). Britain's firearm death rate has been about 0.3 in 100 000 while the corresponding US rate is 10.6.

(Arya 2002). Suicides and homicides have contributed equally to total firearm deaths in the United States, but most firearm deaths are suicides (71%) in high-income countries and homicides (72%) in upper-middle-income countries (Krug et al 1998)

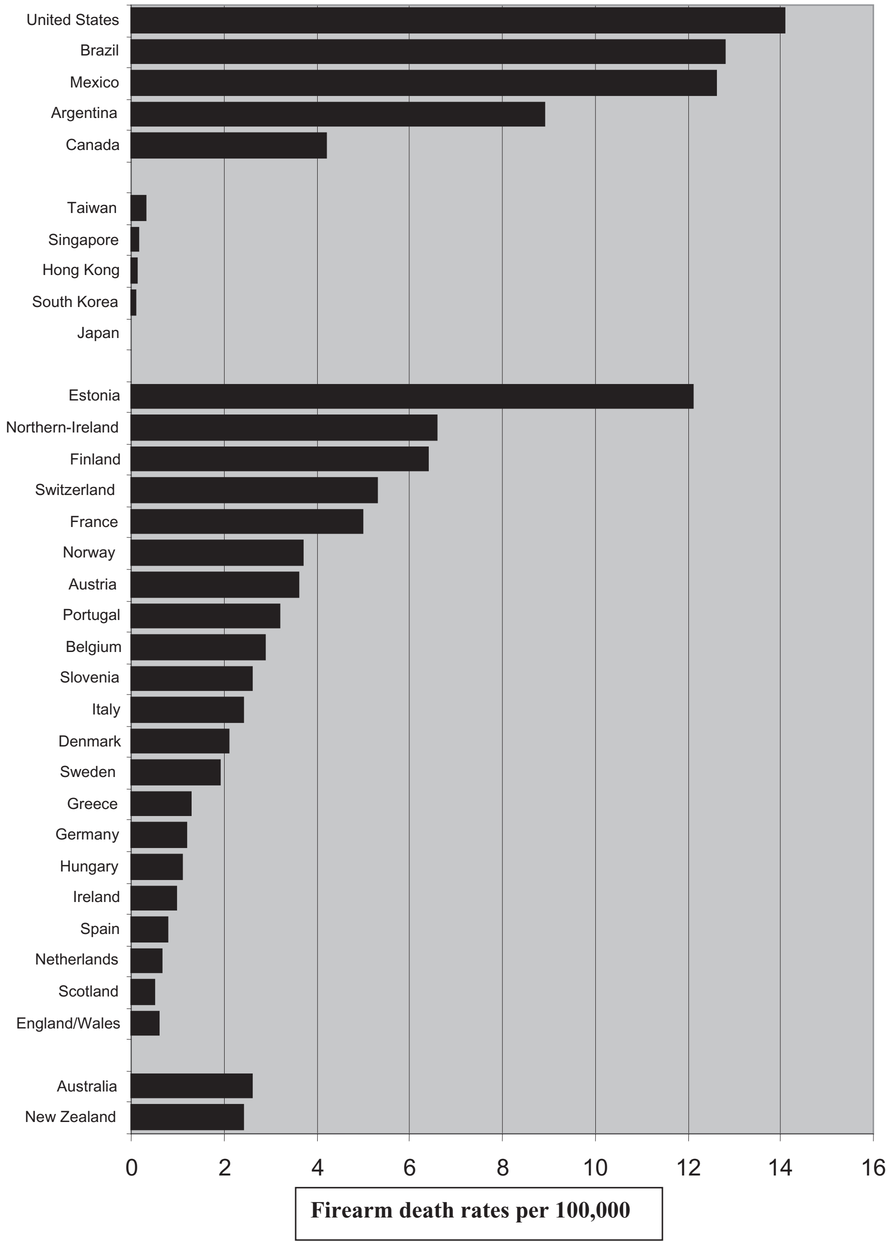

Figure 3. Firearm-related deaths in the United States and 35 other high- and upper-middle-income countries by Krug et al. (1998).

2.3 Epidemiology in the United States

In 1999, the United States reported over 28 000 deaths a year from small arms accidents, suicides, and homicides, which is the highest rate in the developed world (Centers ... 1999, MacKenzie 2004). In American rural areas, firearms are the leading cause of death among 15–24 year-olds, slightly ahead of vehicle crashes, and the third leading cause of death in those aged under 15 (Centers ... 1999).

From the mid-1980s, the age-adjusted firearm death rate rose steadily, from 12.7 per 100 000 in 1985 to 15.6 per 100 000 in 1993 (MacKenzie and Fowler 2004, Fingerhut and Warner 1997). The increase has been explained almost exclusively by a rise in firearm homicides among adolescents and young adults aged 15 to 34. In this age group alone, the firearm homicide rates increased by 83% between 1985 and 1993, from 8.7 to 15.9 per 100 000. Since 1993, however, the rate of firearm deaths has been steadily falling. The rate in 1999 was 10.6 per 100 000, the lowest in two decades. A decline has been observed in both firearm homicides and suicides, although the rate has been higher in firearm homicides. The declines in rates were consistent across age groups. (MacKenzie and Fowler 2004)

While the US murder rate without guns is roughly equivalent to that of Canada (1.3 times), its murder rate with handguns is 15 times the Canadian rate (Cukier 1998). Countries with similar cultural, economic, and ethnic make-up but with different gun possession rates also indicate widely differing firearm death rates, roughly correlating with the percentage of households with guns. Households with firearms are three times more likely to commit murders and five times more likely to commit suicides (due to all causes) than similar households without firearms. These data suggest that firearm deaths may be preventable by controlling the supply and possession of guns (Arya 2002). In the United States, the costs of hospitalization of patients with firearm injuries have been estimated to exceed one billion dollars per year (Lee et al. 1991).

2.4 Epidemiology in Europe

In reviewing the data available on the mortality and morbidity caused by civilian use of firearms, striking differences are found within the Western world (Böstman et al. 1992). Overall, epidemiologic studies in Europe are sparse, and in the Nordic countries only a few epidemiologic studies on firearm injuries have been published since the 1980s (Mäkitie et al. 1996, Ponzer et al 1995, Ponzer et al. 1998).

Traditionally, firearm injuries have been considered a minor problem in Europe due to the restrictive legislation requlating the civilian possession and use of firearms in these societies. In central Europe, gunshot wounds account for only a small percentage of the total number of trauma cases seen. A recent study showed that in Germany only 0.065% of trauma cases were associated with gunshot incidents (Bauer et al. 1992), and further, that more than two thirds of fatal gunshots were classified as suicides, one third as homicides, and only 3% as accidents (Koops et al. 1994). In the United Kingdom, although the trend of penetrating firearm injuries has been rising, they remain rare (Ryan and Rich 1997).

In Sweden, firearm injuries were accidental in 58% of the cases, due to suicide or attempted suicide in 11.7%, due to murder or attempted murder in 20%, and in 12% of the cases, the background remained undetermined (Ponzer et al 1995). Further, males, single individuals, and Finnish immigrants treated for firearm injuries were more likely to be convicted criminals and to have committed crimes of violence than members in a control group (Ponzer et al. 1998). Furthermore, suicides by firearms were three to four times as common as homicides, and only a very small amount were accidents or "undetermined" gunshot fatalities (Karlsson et al. 1993). In Finland, the situation is largely the same.

According to recent data from e.g. Sweden versus the United States, the total number of firearm-related deaths per 100 000 person-years was approximately five times higher in the United States, the difference being even greater for nonfatal injuries (Mercy and Houk 1988, Nelson et al. 1987, Nyman 1990, Örnehult and Eriksson 1987).

2.5 Epidemiology in Finland

Of the European countries, Finland was recently reported as having the third highest death rates associated with firearms after Estonia and Northern Ireland (Krug et al.1998). From 1985 to 2004, the role of deaths, in general terms, caused by firearms has been identified in Finland (Figure 4) (Mäkitie and Paloneva 1997, CDS). These reports were compiled using data from the Statistics Finland, placing deaths caused by firearms into a separate category. Unfortunately, the ICD-9 classification included firearm- and explosion-injuries in the same bracket with suicides and homicides until 1995. On the other hand, true explosion deaths have been rarities in the country during the same period (Mäkitie and Paloneva 1997). Therefore, the data on firearm related deaths is accurate, reliable, and closely reflects the actual incidence as reported in corresponding studies.

The results indicated that firearm related deaths have slightly decreased in the country since the 1980s (Figure 4). However, this is only a general impression, because the public statistics provide information on national level and no regional or situational behavioral theories can be drawn without a more critical analysis.

Suicides constitute a significant public health problem in Finland, especially among men. According to WHO statistics (2000), the suicide rate of Finnish men is the seventh highest in Europe and the suicide mortality of Finnish women is slightly over the average. Suicide is the most common way of dying among Finnish men aged 20 to 34 years (Öhberg et al. 1993).

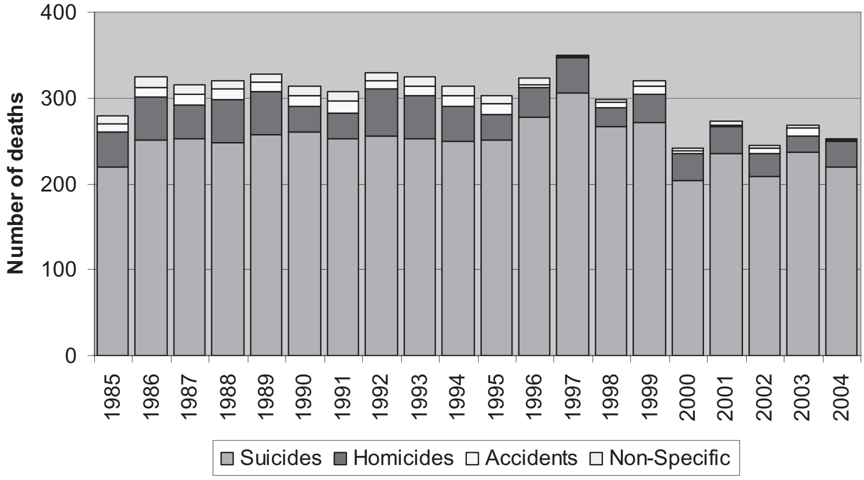

Figure 4. Firearm- and explosion-related deaths in Finland 1985-2004 by Mäkitie and Paloneva (1997), and by CDS.

Between 1947 and 1990, the suicide rate among Finnish men (age >14 years), increased from 39.7 to 61.7 per 100 000 population. This increase was observed in all age-groups. After that, from 1990 to 1995, the total suicide rate began to decline. The largest change was noted among the 15–24-year age group. During the whole period, hanging and firearms were the most common methods of suicide among men. In 1995, these two methods accounted for 30.2% and 25.6% of all male suicides, respectively (Öhberg et al. 1993).

The same kind of development has been ascertained among Finnish women. Between 1947 and 1995, the suicide rate of Finnish women (age >14 years) increased from 7.1 to 14.4 per 200 000 population. This change was evident in all age groups, but only among the middle-aged was the increase statistically significant. This is due to the rather small total number of female suicides. Firearms represent a relatively rare method of suicide among women. In 1995, only 4.9% of all female suicides were committed by firearms (Öhberg et al. 1998).

The author is unaware of purely nation-based studies on firearm injuries in Finland before the late 1980s. However, in the Finnish Defense Forces (FDF), ballistic injuries have been studied from the early 1980s. These injuries have not been common during military service in Finland (Mäkitie et al 1995). When studying men serving in the Finnish Defense Forces, using firearms is the most common (51%) method of committing suicide. However, the overall suicide rate in conscripts is lower than in men of the same age group not in military service (Mäkitie and Paloneva 1997).

3. Firearm Injuries of the Extremities

Treatment of ballistic traumas of the limbs represents a significant share of all traumas, particularly in civilian practice (Farquharson et al. 1997). Also, wounds to the extremities account for two-thirds of all wartime injuries of the survivors.

As civilian low-velocity gunshot wounds seldom result in severe injuries of the extremities (Geissler et al. 1990, Woloszyn et al. 1988), the majority of the serious permanent disabilities identified in patients are likely due to irreversible damage to neural tissue, i.e. brain or spinal cord. Patients surviving a craniocerebral missile injury, civilian or non-civilian, have shown high morbidity scores (Byrnes et al. 1974, Hammon et a.l 1971).

Principally, there exist two types of gunshot wounds: an uncomplicated, simple soft tissue lesion and a complicated, multiple tissue lesion. A civilian type of missile wound is usually caused by the so-called low-velocity mechanism, and they often are uncomplicated (Ordog 1988). However, Coupland's words "the surgeon rarely knows the weapon, nor is there a uniform pattern of wounding" (Coupland 1993) hit the nail on the head and could be used as a motto when treating a firearm injury.

The demand presented by ballistic wounds on the selection of surgical techniques depends largely on the degree of wound severity. The International Red Cross clinical classification, intended specifically for field use, provides an easy and time-saving system for scoring the severity of ballistic wounds. Scoring is based on the following six main wound features: skin wounds, i.e. maximum diameters of entry and exit wounds (X), size of cavity or no cavity (C), injury to vital structures (V), fracture (F), and visible metallic bodies, i.e. bullets or fragments, within wound (M). The total sum of the scores indicates the severity of a wound indicates the severity of a wound of an extremity – the higher the sum, the more severe the injury (Coupland 1993).

The points for entry (E) and exit (X) maximum diameters are given in centimeters, thus the absence of an exit wound gets the value rating of zero points. The size of the cavity (C) is scored according to whether or not it can take two fingers before surgery, with "yes" receiving 1 point and "no" receiving 0 point. The scores for injury to vital structures are (e.g. brain, viscera, or major vessels (V)): no = 0, yes = 1, and significant = 2 points. Fracture scores (F) are between 0 and 2 points: a hole, a simple fracture, or insignificant communition receive 1 point and a clinical significancy receives 2 points. No metallic bodies (M) or bone fragments (secondary missiles) within the wound on radiologic examination equal 0 points, one body receives 1 point, and multiple bodies 2 points (Figure 5).

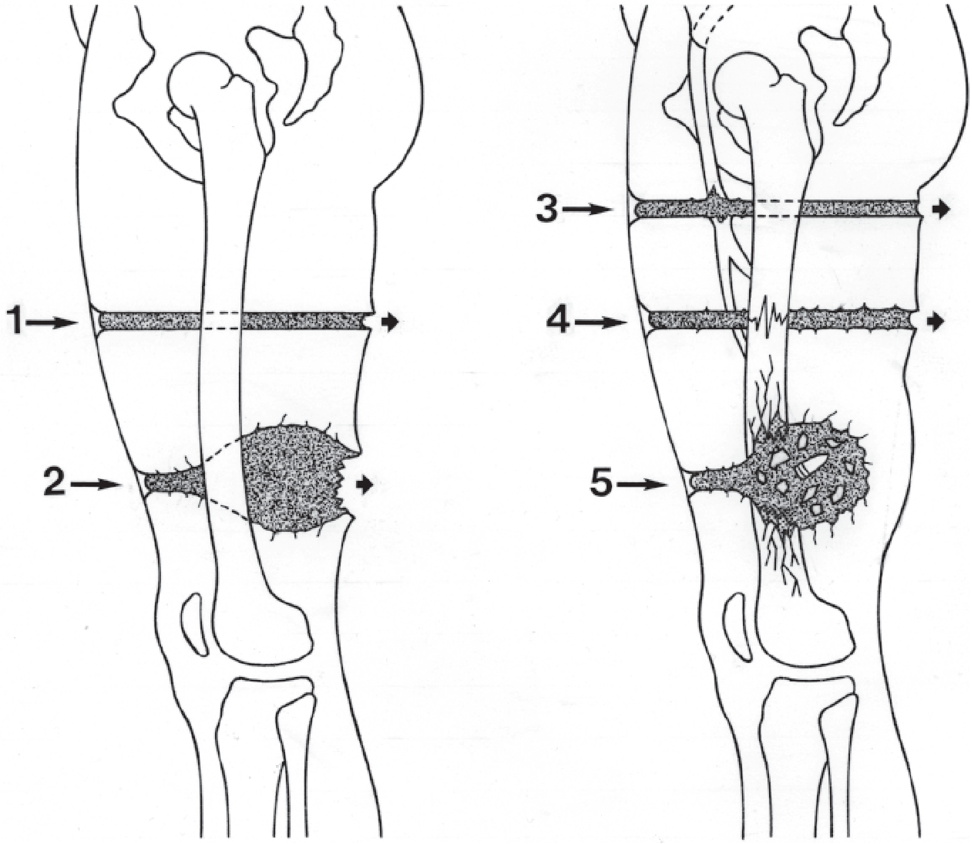

Figure 5. Examples of ballistic wounds and scoring.

1) **Simple soft tissue injury by low-velocity bullet with 1 cm entry and exit skin wounds and scoring 2 points.**
2) **Soft tissue injury due to high-velocity bullet. Entry wound 2 cm and exit wound 8 cm and wound cavity over 2 fingers. Total 12 points.**
3) **Injury of vital vessel by low-velocity bullet. Entry and exit wounds 1 cm each, significant injury of femoral artery 2 points. Total score 4 points.**
4) **Entry and exit wounds by low velocity-bullet. 1 cm each, simple transverse fracture 1 point. Total score 3 points.**
5) **Entry wound by high-velocity bullet. 1,5 cm or 1.5 points. No exit wound or 0 points. Wound cavity 1 point, clinically significant comminuted fracture 2 points, and one visible metallic body (bullet) 1 point. Total 5.5 points. (©Research Institute of Military Medicine / Larni HM and Mäkitie I 2006).**

3.1 Gunshot fractures

In the Finnish civilian material, injuries of the extremities have predominated in the late 1980s (Böstman et al. 1992). The American trauma surgeons are accustomed to confronting gunshot wounds to the extremities on a daily basis. In an American study on 132 fractures of the extremities secondary to gunshot wounds, the most common sites were the lower leg, the foot, and the forearm (Woloszyn et al. 1988).

Böstman et al, in their study of firearm injuries involving the skeleton, reported that the skeleton, excluding the skull and the facial bones, was affected in 169 of a total of 1268 hospital in-patients during a 5-year period. Accidental gunshots comprised the majority, 66%, followed by domestic conflicts and assaults, 19%. The male:female ratio was 11:1. The median age of the patients was 31 years. The distribution according to the principal skeletal injury was as follows: spinal column 22, pelvis 2, scapula 2, humerus 12, forearm bones 22, hand bones 13, femur 57, lower leg bones 21, and foot bones 18 patients. The mean ±SD duration of the hospital stay was 13.9 ± 4.5 days. The longest average hospital stay was recorded for gunshot fractures of the tibia, 20.1 days (Böstman et al. 1992).

3.2 Vascular injuries

Vessels exposed to the effects of ballistic missiles behave in a rather unpredictable manner (Ryan and Rich 1997). In case of blood vessels, cavitation may lead to considerable distortion with little external evidence of injury. The diagnosis of vascular injuries may be difficult and, since the haemorrhagic and ischemic consequences of a missed diagnosis may be severe, constant vigil is essential at the initial assessment and during follow-up. The vascular reconstruction method chosen will depend on the type and site of injury.

Continued improvements in limb salvage after vascular injuries in the lower as well as upper extremities has been the focus of many studies (Feliciano et al. 1988, Trooskin et al 1993, Grossman et al. 1999).

In the United States, gunshots were the etiologic factor in 21% of vascular traumas of the extremities in a civilian series of 5760 cardiovascular injuries (Mattox et al. 1989). Further, in a series of 320 gunshot injuries to the extremities treated at an urban trauma center, 21% presented with a vascular injury (Trooskin et al. 1993). Another report from the United States described nineteen out of 100 patients who had sustained isolated below-the-knee gunshot wounds and exhibited vascular injuries (Grossman et al. 1999). In the United Kingdom, in a series of 23 shotgun wounds of the limbs, there were six patients with severe vascular injuries (Stewart et al. 1993). A more recent British study reports a four-fold increase in civilian gunshot injuries to the extremities, but vascular injuries were limited to one case only (Persad et al. 2005). An earlier report from South

Africa described a two-year follow-up from a university hospital with 173 major arterial injuries in about 4000 patients with gunshot injuries to the extremities (Degiannis et al. 1995).

Despite the growing political unification within the European Union and the free and increasingly rapid flow of information through the surgical world, there is no single European experience in the management of vascular injuries, but rather a multitude of experiences reflecting each country´s traditions, surgical know-how, and special circumstances (Fingerhut et al. 2002).

4. Epidemiology of Explosion Injuries

Explosion-related injuries and deaths have previously been most numerous during the time of war. In the recent past, they have also represented an increasing problem for many countries not at war, partly because of terrorist activities that often involve use of explosives (Mellor and Cooper 1989, Frykberg 2002). Recent studies from other countries have shown an increased medical interest in these kind of injuries, obviously due to the possibility of further assaults by terrorists (Frykberg 2002, Kluger et al. 2004).

In times of war, injuries and deaths from explosion have not been infrequent nor unexpected. There is evidence, however, that with terrorist activities, often involving use of explosives, similar events have spread to otherwise peaceful countries where their occurrence is far from expected (Mellor and Cooper 1989, Frykberg 2002). Consequently, as corroborated by some recent studies, the medical interest in these kind of injuries is currently on the rise (Frykberg 2002, Kluger et al. 2004).

Apart from one Swedish report (Rajs et al. 1987), there is a deficiency of nationwide, population based reports on morbidity and mortality from explosion-related injuries in civilian communities. Evidence of illegal possession of explosives and the resulting fatal and non-fatal injuries are, however, abundant in the literature (Abenheim et al. 1992, Karmy-Jones et al. 1994): in fireworks (Blanco-Pampin 2001, See and Lo 1994), in military conflicts (Coupland 1993, Karsenty E et al. 1991), in tire and wheel handling (Suruda et al. 1991), in terrorist activities (Mellor and Cooper 1989, Frykberg 2002, Frykberg and Tepas 1988, Thompson et al. 2004), in underwater incidences (Petri et al. 2001), and in suicides (Shields et al. 2003).

From the medical point of view, life-threatening explosion injuries present remarkable challenges. The diagnosis and treatment of severe explosion injuries can be further complicated in the event that survivors sustain multiple injuries. However, injuries may remain less severe as well. This was the case in a civilian European incident, where the majority of casualties sustained only minor injuries (Carley and Mackway-Jones 1997).

Explosion injuries may remain less severe, as was the case in a civilian European incident documented by Carley and Mackway-Jones where the injuries remained mostly minor (Carley and Mackway-Jones 1997). Principally, however, the injuries result from life-threatening explosions, they are serious, even multiple, and usually challenging to the attending medical staff.

Finland has witnessed only three major explosion accidents over the last three decades: cartridge factory explosion in Lapua in 1976, accidental grenade explosion in the Finnish Defense Forces in 1984, and homemade bomb explosion by an individual in a Vantaa shopping center in 2002 (Kekki 1976, Laapio 1985, Pekkarinen 2002). Forty-seven people died in these accidents.

It cannot be overlooked that two unintentional explosion incidents with 11 casualties, one conscript dead and 10 injured, have recently occurred in the Finnish Defense Forces in spite of strict security measures (Mäkitie et al. 2002, Finnish Defense Forces 2005). Also, it appears that explosion-related injuries have generally been little studied in Finland, since only studies on injuries from fireworks and from explosions in the Finnish Defense Forces have been published (Rudanko and Winell 1995, Raatikainen et al. 1996, Mäkitie et al. 1995, Mäkitie et al. 2002).

5. Other Deleterious Health Effects of Shooting

Few epidemiologic studies on shooting with firearms and its effects on health have been published in Finland. However, an idea about the incidence and type of the different kinds of health effects can be drawn from the compensations paid by the insurance companies. Every recreational or sports shooter and hunter who is a member of a central organization (The Finnish Shooting Sport Federation or Hunter´s Central Organization) has an insurance for accidents occurring during shooting or hunting. Over the period of 1995 to 1998, there were 52 compensated accidents among sport shooters. However, none of these were due to ballistic traumas (Vessari 2001).

In addition to the direct ballistic injuries caused by bullets and explosives, firearms and explosions also associated with other, more indirect deleterious effects, such as acoustic traumas and emission of airborne elemental pollutants.

Acoustic traumas

Acute acoustic traumas (AATs) due to impulse noise are still relatively common among conscripts in the Finnish Defense Forces, with an incidence of apprx. 1700 per 100 000 person-years (Ylikoski and Ylikoski 1994, Savolainen and Lehtomäki 2005).

In a recent study, AATs in Finnish conscripts were found to be most frequently caused by rifle-caliber weapons (86.6%), and by assault rifles in particular (82.4%) (Savolainen and Lehtomäki 2005). At the moment AAT occurred, only 3.6 per cent of the conscripts wore hearing protection in accordance with army ordinance. Accidental firing was the most common single reason (68.8%) for the lack of hearing protection. According to this study, AATs occurred mainly (86.1%) when blank cartridges were used and were caused by a shot fired by an adjacent conscript in 73.8% of the cases. Firing one's own weapon was the etiologic factor in 26.2%. It is noteworthy that not a single shot was fired accidentally when live ammunition was used (Savolainen and Lehtomäki 2005).

Another recent Finnish case study of a shopping mall bomb explosion suggests that an otologic consultation, or at least an audiometric screening test to exclude hearing impairment, should be performed regardless of symptoms, on the basis of exposure data only (Mrena et al. 2004).

6. Prevention Strategies of Ballistic Trauma

6.1 General background

The importance of injury prevention efforts is pointed out by trauma mortality patterns. One-third to one-half of trauma deaths occur in the field (Baker et al. 1980, Mock et al. 1998, Sauaia et al. 1985), even in locations with availability of the most advanced trauma treatment systems. Such deaths can be avoided only through effective prevention efforts (MacKenzie and Fowler 2004).

Almost all trauma prevention strategies can be conceptually derived from Haddon's strategies (MacKenzie and Fowler 2004), described in the introduction chapter of the present study. In general, interventions can be thought of as either active or passive on the part of the person being protected (MacKenzie and Fowler 2004). For trauma prevention, passive interventions have usually been considered more reliable than active ones (Haddon 1980).

Clinicians are most interested in the nature of the injury, since this determines the type of treatment and operation required. Hospital managers are interested in the nature of injuries as well as the ensuing surgical procedures, since these affect the budgets, facilities and personnel needed to provide the treatment. Epidemiologists, on the other hand, are more interested in whether a fall was from a motorcycle or a tree than in the precise details of the injury and treatment. Fortunately, it is relatively simple to modify hospital records and coding to provide the information needed for injury control (Barss 1998).

While the information from a single death can be useful, the power of modern epidemiology to identify causes and determinants of injury is most compellingly revealed only after the compilation and analysis of highly specific data from many deaths of particular types (Barss 1998).

One of the controversial issues discussed in a variety of analyses is the gun control legislation. Gun-related deaths and injuries are rare in most countries where the ownership of guns is tightly controlled or prohibited for most people.

The population rate of all assaults in a region of Denmark in a year was about 75 percent of that in a northeastern Ohio trauma study, but the Danish homicide rate was only 20 percent of that in the Ohio study. The difference in the homicide rates is mainly the result of a greater use of guns in assaults in Ohio. In Denmark, private ownership of a gun was allowed for hunting only (Baker 1985).

In communities where firearms are widespread, access to such weapons in a household can increase the risk of suicide by as much as tenfold in the 15–24-year age group (Kellerman and Reay 1986). In countries where firearms are less easily available, other methods of suicide are favored. Nevertheless, increasing militarization and sales of firearms, with growing numbers of weapons and ammunition stored in households, will strengthen the familiarity with guns as a method of suicide in the future (Barss 1998).

In the United States, where lethal and concealable weapons, such as handguns (pistols and handguns), are widely available, homicide rates are several times higher than in other industrialized nations. However, it would be an oversimplification to attribute the extreme rates of homicides in the United States to the large numbers of handguns only, while ignoring their underlying social and political factors, such as poverty, large disparities in wealth, a heterogeneous ethnic mix, and freely available alcohol and other drugs linked with an abundance of addicts. The easy access to lethal firearms in the domestic environment undoubtedly contributes to the likelihood of fatal outcomes in many conflicts (Kellerman and Reay 1986, Sloan et al. 1988).

Ever since various countries have imposed strict gun controls, long-term comparisons of trends for violent crime have indicated substantial effectiveness of such laws, but the weaker gun control laws typical of the United States have shown no discernible effects (Podell and Archer 1994).

Opponents to gun control laws point at low gun death rates in Israel and Switzerland, where high numbers of citizens keep guns at home as part of the reserve defense forces. Important questions for research are: What criteria do these countries use to screen applicants for the defense reserves? How is the screening implemented? How many people are eligible to keep guns on the basis of the screening? Do the citizen-soldiers have loaded guns or are there conditions for issuance of ammunition? Does the recipient of ammunition have to account for its whereabouts and use? The answers might provide guidance for more effective gun control in countries where guns are ubiquitous and where gun death rates are high (Robertson 1998).

The effects of gun control on suicide rates are less controversial. Researchers who have examined these effects on homicide rates found that suicide rates are substantially lower in areas with strict gun control laws (Medoff and Maqaddino 1983).

Generally, the effects of laws on behavior and the evaluation of the effects are enhanced if the behavior is easily observable. If the researchers can observe the behavior, so can the police. It is not surprising, therefore, that laws requiring observable behavior, such as limits on vehicle speed, seat belt use, and motorcycle helmet use are usually more effective than laws directed at phenomena not observable without stopping persons – such as limits on drivers' blood alcohol content or the carrying on person of concealed weapons (Robertson 1983).

The British Medical Journal in its editorial (Arya 2002) brought up the issue of confrontation with a small arms pandemic in the medical sphere: Physicians throughout the world bear witness to the terrible consequences of small arms. But do we truly comprehend the impact and the epidemiology of a small arms pandemic, and can we devise effective strategies for its prevention the way we have for other major public health issues? The capacity for collecting consistent, reliable, and relevant data is limited by various cultural, economic, infrastructural, and logistic factors even in developed countries not at war. Nevertheless, there are some solid data on the size of the problem and on the indicators suggestive of possible solutions (Arya 2002).

In injury control, recognition of the problem alone is not enough. However, interventions that are introduced to protect high-risk individuals also provide the most effective protection for the general population (Barss 1998).

In a meritorious article, "Firearm related deaths: the impact of regulatory reform" published in Injury Prevention in 2004, Ozanne-Smith et al. also gave detailed information on the firearm reform in Australia after the 1996 nationwide agreement and the responses in Victoria through the Firearms Act 1996 and the Firearms (Amendment) Act 1998 (Ozanne-Smith et al. 2004). Arguments and reasons for supporting denial of the legal permission to purchase or possess firearms and the influence of regulatory reform on firearm related deaths have also been discussed in Finland (Mäkitie et al. 2006). This review emphasizes the limitations of firearm licensing schemes, choice of handguns, and storage of firearms in the country.

6.2 American strategies for reducing deaths and injuries from firearms

Karlson and Hargarten reported in 1997 that deaths and injuries from guns are an enormous problem in the United States. But, as with other big problems in American industrialized corporate economy, it is a problem that human beings created and one which they can creatively solve (Karlson and Harqarten 1997).

Solutions to the problem would be to make changes to guns themselves, to restrict the easy availability of most guns in the society, and to change citizens' incentives to own and use guns. One of the messages in this chapter is that a variety of solutions are already being proposed.

Because the "gun problem" is so huge and multifactorial, there is no panacea, no single solution that will make everything all right. Public health advocates, and others, must try many different methods and push to have them evaluated carefully, so we know what works and why and what does not work and should not be tried again.

Part of the strategy in the United States is to expand the narrow focus on "gun control" – keeping guns away from criminals – to include other approaches based on the science of injury control. One part of this strategy is to consider guns as consumer products, another is to focus interventions on high-risk populations, high-risk situations, and weapon types that increase the probability of injury or death.

We know that rewarding results in reducing injuries and deaths can be achieved if changes are made to the product or if access to the product is restricted. The least effective of impacts on the population are the efforts to change the ways how individuals use the product. In medical work with motor vehicle caused traumas, we have learnt that death rates from frontal collisions are more likely to fall by virtue of built-in airbags in cars rather than by laws requiring seat belt use. We also know, however, that in the absence of airbags, seatbelt laws were more effective than persuading millions of individuals to voluntarily buckle up. A prerequisite to any seat belt use, of course, was the requirement that manufacturers equip cars with seat belts, which was not routinely done until the mid-1960s.

Changing individual behaviors solely through education is hard work. Even successful education programs may not be effective, since people must take proper action each time they handle a gun if they are to protect themselves and their families. Changing the behavior of firearms manufacturers is also hard work and may not be accomplished without federal mandates. However, once accomplished, the consequences will be beneficial, because the products will have undergone alterations before they reach civilian hands.

Although the view is controversial, we believe that in order to reduce injuries and deaths, the society has to limit the availability of most guns and ammunitions. This might be achieved by implementing price increases for the product, tax increases for manufacture or sale, or by renewing legal sales practices while interrupting illegal ones. Furthermore, we must put an end to easy access to guns at moments when impetuous action can result in deaths. This means addressing the ease with which people are allowed to carry guns on their persons, and revising the incentives promoting easy availability, ownership and use of guns.

Fundamentally, injury control training teaches the fallacy of the slogan, “Guns don’t kill people, people kill people” (Karlson and Harqarten 1997).

6.3 Finnish legislation concerning small arms

6.3.1 Acts of violence

Homicides and attempted homicides

Over the period of 1989–1998, the annual rate of homicides recorded by the police has varied between 113 and 155. Besides homicides, the Finnish law also distinguishes assaults resulting in death, the number of which has varied between 21 and 39 during the same decade. The number of these two crimes combined has varied between 145 and 185, indicating a mortality of about 3,5 per 100 000 inhabitants (Vessari et al. 2001).

During the last fourty years, of all the homicides, the proportion of those killed by gunshot has been relatively steady, the average being 23,3%. From 1985 to 1994, the proportion was higher than the average (from 25% to 26%), but the reason for this is unknown (Vessari et al. 2001).

Even though the proportion of firearm homicides has been quite steady, the risk of death by shooting has risen. However, this rise is not linked to any specific method of homicide, but rather can be explained by the increase in the overall amount of homicides (Vessari et al. 2001).

6.3.2 Finnish small arms legislation

The Finnish legislation concerning small arms has recently been revised. The first revision was enacted in 1998, the second revision in 2002. The new Firearms Act imposed changes on the possession, trade and import of small arms. Also some administrational changes took place.

The game act law, as well as its by-laws, came into force in 1993. It prescribed an addition to the existing laws on storing firearms to the effect that a person owning a particularly dangerous firearm, or five or more firearms, is now obliged to store them in a specific, locked firearm container. If, however, the local police has approved the premises where firearms are stored, this kind of container is not needed.

The process of obtaining a permit for a gas spray will be simplified, because a gas spray is not considered as dangerous as a firearm. Additionally, a spray can easily expire in five years and the present system is rather bureaucratic when renewing the permit for a new canister.

The administration of the small arms issues will be centralized to the Firearm Administration Unit, operating within the Ministry of Interior. This unit will assume the same duties as have been performed by the Provincial State Offices. Within the Firearm Administration Unit, a firearm board will reside to give statements concerning the interpretation of the Firearms Act.

Despite the recent amendments to the Finnish Firearms Act, the necessity of additional elements to the Act have already been expressed, such as centralized firearms registration system and a new secondary law concerning security services.

Aims of the Study

1) To investigate the occurrence and nature of non-fatal firearm injuries in Finland
2) To investigate the occurrence and nature of fatal firearm injuries in Finland
3) To evaluate severe gunshot injuries of the extremities in Finland
4) To investigate the occurrence and nature of non-fatal explosion injuries in Finland
5) To investigate the occurrence and nature of fatal explosion injuries in Finland
6) To identify and develop control strategies for firearm injuries in Finland

Material and Methods

The study presented here is population based, nationwide, and descriptive in nature. All data on non-fatal injuries is based on the Finnish National Hospital Discharge Register (NHDR) and on original hospital records. Data on fatal injuries is based on the official Cause-of-Death Statistics (CDS) and on the original death certificates from the Archive of Death Certificates (ACD), both at Statistics Finland.

Non-fatal firearm injuries (Studies I–II)

Study design and setting (Study I)

In the first study over a 5-year period from January 1985 to December 1989, the records of the Central Medical Board were analyzed for all patients admitted alive to the hospitals of Finland due to physical injuries caused by gunshot. Data on victims dead on the scene of the shooting or dying during transport to hospitals were collected from the statistics of the forensic medical authorities.

The material obtained for the first study was analyzed for demographic data, mode of the shooting incident, possible geographic variation in the incidence, anatomic distribution of the injuries, and duration of the hospital stay.

Study design and setting (Study II)

The second study was a hospital discharge register based study covering the period from January 1, 1990 to December 31, 2003. Data on injury hospitalizations were obtained from the National Hospital Discharge Register (NHDR) in Finland, which contains data on age, sex, place of residence, hospital and department, day of admission and discharge, diagnosis, location and cause of injury, and whether injury was unintentional, self-inflicted or assault. The NHDR was established in 1967, and is updated and monitored for quality by the Department of Registers and Statistics, National Research and Development Center for Welfare and Health, Helsinki, Finland.

Selection of cases for the second study

For the purpose of this second study, a firearm-related injury was defined as an acute, physical injury caused by gunshot. Accordingly, all firearm-related injuries between 1990 and 2003 were selected from the NHDR and the unit of analysis was the injury hospitalization. The primary diagnosis and the unique personal identification number allowed us to focus our analysis on each patient's first recorded admission. Several admissions of a single patient were included only if the year of admission and the year of primary diagnosis were different. The length of hospitalization was used to describe the use of hospital resources as well as the severity of the firearm-related injury.

The diagnosis and cause of injury were coded using the Ninth (1990-1995), the Tenth (first edition) (1996-1998) and the Tenth (second edition) (1999-2003) revisions of the International Classification of Diseases (ICD). To identify firearm injury hospitalizations, we selected ICD-9 E-codes (E925, E955, E964 and E974), ICD-10 (first edition) external causes: (W32-W34, X72-X74, X93-X95, Y22-Y24), and ICD-10 (second edition) external causes: (W32-34, W43, X72-74, X93-95 and Y22-24). Precise information about the types of firearms used could not be obtained, because such data is not systematically collected to the NHDR. Concerning diagnosis, we recoded the more specific ICD-10 codes into less specific ICD-9 codes one by one for the analysis, because the ICD-coding system used by the NHDR had been changed during our study period. Since we were interested in the firearm-related physical injuries, only hospital admissions with the primary diagnosis of an acute injury (ICD-9 codes) 800-957, excluding late effects (905-909), were included in our analysis.

Methods of measurement and primary data analysis

SPSS 12.0.1 for Windows and StatXact-4 were used for the statistical analysis. We calculated the overall incidence rates and the age- and sex-specific incidence rates (per 100 000 persons) by dividing the number of cases with firearm-related hospitalization by the midyear annual population of the specific age and sex group. The annual midyear population data was obtained from Statistics Finland, the official population register in the country. The total population varied between 4 998 478 in 1990 and 5 219 732 in 2003. When calculating the cumulative incidence across the 14-year period, the sum of the annual midyear populations was used. Descriptive statistics (cross tabulations, frequency distributions, means, medians and interquartile range) and c^2 -test were used to compare proportions. Ninety-five percent confidence intervals (95% CI) were calculated for incidence and incidence rate ratios. Incidence trends were calculated by Cochran-Armitage trend test. The Institutional Review Board approval was obtained from the Ministry of Social Affairs and Health Finland (IRB number 23/07/2001).

Fatal firearm injuries (Study III)

Data on all firearm-related deaths during the 10-year period from January 1990 to December 1999 were collected from the National Register of Deaths maintained by Statistics Finland. Copies of original death certificates of individuals who had died from firearm injuries were obtained and reviewed from the Archive of Death Certificates, Statistics Finland.

In Finland, the law requires autopsy of all deaths caused by crime or accident or when death has been sudden or unexpected. In practice, autopsy takes place following almost all fatal accidents, especially when a firearm has been involved. Death certificates had been appropriately issued by experts in forensic medicine for all cases in this study. The data contained in the certificates and relating to firearm injuries and deaths could be considered reliable, reflecting the true incidence.

Data relating to demographics, nature of the shooting, anatomic site of the fatal injury, place of death, and duration of hospital stay were collected and analyzed. Suicides were excluded.

Laboratory findings indicating that a victim had drunk alcohol or taken illegal drugs before the fatal firearm-related injury were recorded from the death certificates. Precise information about the types of firearms used could not be obtained, because such data was not available from the death certificates.

In the International Classification of Diseases (ICD) versions 9 and 10, deaths resulting from use of firearms are categorized as suicides, homicides, accidents, and non-specific events. In the study reported here, firearm-related deaths for which no obvious external reason could be discovered were categorized as non-specific events by the forensic authorities. In such cases, there had usually been neither witnesses to the shooting nor was there any indication that it had been undertaken deliberately or with the intention of suicide.

Gunshot fractures (Study IV)

Patients and methods

Over a 5-year period (from 1985 to 1989), data were collected on all patients treated at Finnish hospitals for gunshot injuries by using the statistics of the Central Medical Board, the records of discharge diagnoses, and the hospital patient records. This information was analyzed for demographic details, noting consumption of hospital resources, and with special attention paid to gunshot injuries to long bones. Patients dead on admission were not included. The etiology and trauma mechanism were studied. Data retrieved also included age and sex distribution of the victims, location of wounds, fracture classification, early/late treatment of patients, and postoperative complications.

Patients were treated at 11 hospitals, mainly at the central hospitals, but three patients were treated at various district hospitals.

Shock on arrival was defined as a systolic pressure recording of less than 90mm Hg. The gunshot wounds were divided into three categories based on the type of causative weapon: shotgun injuries, rifle (high-velocity assault or hunting rifle), and low-velocity handgun (mainly pistol) gunshot injuries. The handguns had a muzzle velocity of less than 350 m/s. Rifle bullets exceeded a muzzle velocity of 750 m/s, indicating that they were so-called high-velocity projectiles.

Using the grading system of Gustilo et al. (Gustilo et al. 1984), the fractures were classified into three categories: type IIIA-adequate soft tissue coverage of a fractured bone, despite extensive laceration of flaps; type IIIB-extensive soft tissue injury with periosteal stripping and exposure of the bone; and type IIIC-open fracture associated with arterial injury requiring repair.

Vascular gunshot injuries (Study V)

Study design and setting

Information on all severe non-fatal vascular gunshot injury hospitalizations were identified from the National Hospital Discharge Register (NHDR) in Finland. Information on deaths caused by vascular gunshot injuries was obtained from the official Cause-of-Death Register (CDR), an extensive medico-legal investigation system for causes of death in Finland.

The diagnosis and cause of injury were coded using the Ninth (1990–1995), the Tenth (first edition) 1996–1998), and the Tenth (second edition) (1999–2003) revisions of the International Classification of Diseases (ICD) (13). Our study was based on hospital records and death certificates and covered the period from January 1, 1990 to December 31, 1999.

Identification of injuries

For the purpose of this study, a gunshot-related injury was defined as an acute, physical injury caused by gunshot. The corresponding ICD-9 and ICD-10 codes are presented in Table 1. Only hospital admissions with the primary diagnosis of an acute injury were included in our analysis.

Copies of the original hospital records of patients with above selected diagnosis were ordered from the hospitals and reviewed. Seventeen hospitalizations for vascular injuries of the extremities caused by gunshots were found. Moreover, 222 hospitalizations for gunshot fractures were identified. In a critical analysis of these hospital records, six patients were pinpointed with an uncoded, major vascular lesion concurrent with the gunshot fracture. Finally, 37 patients had been treated for gunshot-related amputations, but, in closer examination, only five of these patients could be considered to have had a dominant vascular trauma of the extremity. The majority of gunshot injuries were identified as minor amputations of fingers and toes without problems involving vascular surgery. Shock on arrival was defined as systolic blood pressure recording of less than 90mm Hg.

Fatal cases were identified by obtaining all non-suicidal gunshot-related death certificates with above selected diagnosis from the Archive of Death Certificates at Statistics Finland. The reviewed death certificates indicated that there were only four cases where a major haemorrhage in an extremity was mentioned as the primary cause of death on the scene or during transportation. To sum up for further detailed analysis, a total of 32 patients were identified with severe vascular gunshot-related injuries of the extremities.

The type of causative weapon was divided into three categories when information was available: shotguns, high-velocity (hunting, assault and military rifles) and low-velocity (mainly pistols, including air-rifles) guns.

The incidence rates (per 10 000 000 person-years) were calculated by dividing the number of persons with severe vascular gunshot injury of the extremities during the 10-year period by the sum of the midyear populations (50 986 570) between 1990 and 1999. The population data was obtained from Statistics Finland, the official population register in Finland. Over the study period, the annual population in Finland varied between 4 998 478 and 5 171 302. Ninety-five percent confidence intervals (95% CI) were constructed by Poisson's approximation for incidence.

Explosion injuries (Study VI)

All explosion injuries in the Finnish hospital records from January 1991 to December 1995 were obtained and studied. The classification was based on the International Classification of Diseases (ICD) version 9, containing explosion injuries from pressurized vessels, explosives, fireworks, and other unspecified explosions leading to hospitalization. Also, patients with injuries caused by flying debris from a blast were included in the study. Furthermore, the Statistics Finland was consulted and deaths caused by explosions were obtained from the Cause-of-Death Register.

Between 1991 and 1995, 513 patients were treated for injuries from explosions. Twenty cases were omitted, as the primary injury occurred before 1991. The ICD-9 classification system assigns the same number to cases of suicide and cases of intentional explosions from firearms and explosions. As it was impossible to determine whether these injuries originated from different firearms or explosions, although in most of cases they obviously derived from firearms, these injuries were not included. Altogether, 493 cases remained to be studied (E955A, E964A, E964B, E964X, E974A).

Fatal explosion injuries (Study VII)

Data on explosion-related deaths was obtained from the National Register of Deaths maintained by Statistics Finland, and covered the period from January 1985 to December 2004. Copies of the original death certificates for these individuals were obtained and all certificates indicating death due to explosion-related external causes according to the specifications of the International Classification of Diseases (ICD) versions 9 and 10 were examined. From 1985 to 1995, the codes for the external causes were E924 and E974, and from 1996 to 2003 the codes were W38, W39, W40, X75, Y22, Y23, Y24 and Y25.

We found, however, that the ICD-9 version placed suicides by firearm and by explosion into the same category. In Finland, death by suicide in this category almost always results from use of firearm (Mäkitie 2001). The category of suicides involving guns (or explosives) was, consequently, excluded from the study for the period that ICD-9 was in use.

In Finland, when death is sudden or unexpected, or the result of a crime or accident, an autopsy is required by the law. It follows that an autopsy is performed practically after nearly all fatal accidents, but particularly after those involving an explosion. The death certificates ordered and received for this study covered all cases and were appropriately issued by experts in forensic medicine. We may thus consider them both reliable and as presenting the true incidence of explosion injuries and subsequent deaths. For all subjects of the study, data on demographic background, nature of explosion, anatomic site of injury, duration of hospital stay, and place of death were obtained for analysis as well. Status of possible intoxication or illegal drug or substance use of all subjects was investigated using laboratory findings recorded in the death certificates. Details on the type of explosives involved were unobtainable, because such data was not mentioned in the death certificates.

In the International Classification of Diseases (ICD), versions 9 and 10, deaths resulting from the use of firearms and from explosions are categorized as suicides, homicides, accidents, and non-specific events. When examining explosion-related deaths, we found that deaths for which the forensic authorities had failed to pinpoint the external cause were placed in the category of non-specific events. Typically, these cases did neither implicate any witnesses to the explosion, nor give an indication of deliberate undertaking or of suicidal intention.

Results

1. Epidemiology of firearm injuries

1.1 Hospitalizations 1985–1989 and 1990–2003

The first study showed that a total of 1268 patients were admitted alive to hospitals in Finland for treatment of firearm injuries during the 5-year period of investigation, while 1295 died on the scene of the shooting or during transport to hospital. No increasing or decreasing trend in the incidence rates emerged during this period.

Of the 1268 patients receiving active treatment, 1164 (91,8%) were males and 104 females (8,2%). The mean incidence over a 5-year period in the whole country was 5.1 cases per 100 000 person-years. There was a geographic variation between the five university hospital regions, from 3.6 cases per 100 000 person-years in the southwestern region of Turku to 7.2 cases per 100 000 person-years in the northern region of Oulu. The median age of the patients was 31 years. 273 (21.5%) were under 20 years of age and 134 (10.6%) were 60 years or older.

The mode of the shooting incident was classified as an accident in 725 (57.2%) cases, a suicidal attempt in 255 (20.1%), and an assault (unlawful attack by one person on another) in 158 (12.5%) patients cases. The remaining 130 patients comprised persons subject to legal police intervention and cases where the mode was not classifiable with certainty. The proportion of accidents was highest, 73.3%, in patients under 20 years of age, and lowest, 38.2%, in patients between 40 and 49 years of age. In the latter age group, the highest frequencies of suicidal shootings and assaults were observed, 33.9% and 19.9%, respectively.

The predominant sites of the principal injury were the head in 35.7% and the extremities in 47.6% of the cases (Table 2). For 633 (49.9%) patients, the duration of the hospital stay was less than five days, while 162 (12,8%) needed hospitalization for 20 days or more. The total number of hospital days necessary for patient management was 16 506 and the mean duration of the hospital stay was 13.0 days. There were 39 patients with a hospital stay exceeding 50 days.

During the 14-year follow-up study period, 1990–2003, there were 2504 firearm-related injury hospitalizations in Finland, resulting in an annual injury incidence of 3.5 (95% CI: 3.4–3.6) per 100 000 person-years. Over the period, more than one injury event was counted for 322 people (13% of the injured).

Table 2. Anatomic distributions according to the principal injury in 1268 patients with gunshot wounds, 1985 to 1989.

Location	Number	%
Craniocerebral	183	14.4
Face	270	21.3
Chest including neck	97	7.6
Abdomen	92	7.3
Spine	22	1.7
Upper extremity	250	19.7
Lower extremity	354	27.9

The total number of hospitalizations for firearm-related injuries declined from 254 in 1990 to 133 in 2003 (Table 3). The overall incidence of firearm-related injury hospitalization was 5.1 (95% CI: 4.5-5.7) per 100 000 person-years in 1990 and 2.6 (95% CI: 2.1-3.0) in 2003. The decline was not linear (Table 4). Cochran-Armitage trend test showed a significant decrease in injury incidence trend during the study period (p<0.001). The overall trend and incidence of firearm related hospitalizations from 1985 to 2003 are shown in Figures 6a and 6b. September and October were the months with the highest numbers of firearm-related hospitalizations (Figure 7) .

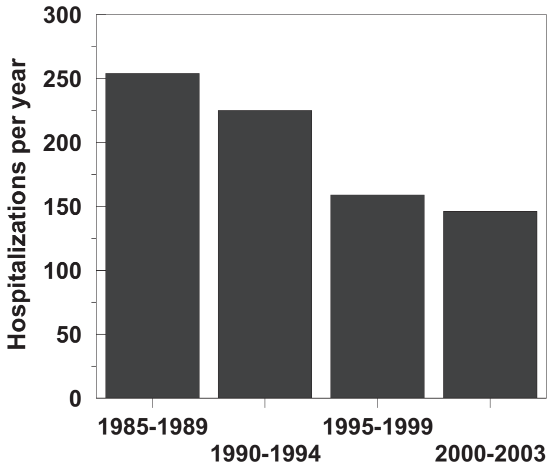

Figure 6a: Annual mean number of fiream hospitalizations

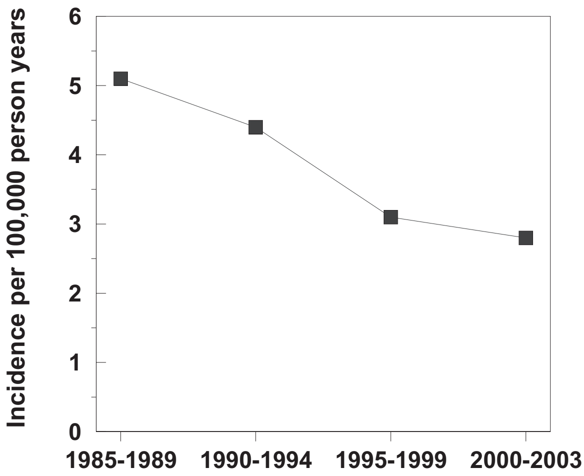

Figure 6b: Annual mean incidence of firearm hospitalizations in Finland

Table 3. Numbers, percentages and incidences of hospitalization for firearm-related injury in Finland in 1990-2003 (N=2504) by sex, age, year, and intent of injury. Population figures are were obtained from Official Statistics of Finland.

Characteristics	No.	%	Rate per 100 000 persons (95% CI)
Sex			
Male	2266	90.5	6.6 (6.3-6.9)
Female	238	9.5	0.7 (0.6-0.7)
Age (years)			
0-14	178	7.1	1.3 (1.1-1.5)
15-24	604	24.1	6.9 (6.3-7.5)
25-34	579	23.1	6.0 (5.5-6.5)
35-44	486	19.4	4.5 (4.1-4.9)
45-55	355	14.2	3.4 (3.1-3.8)
>54	302	12.1	1.7 (1.5-1.9)
Year			
1990	254	10.1	5.1 (4.5-5.7)
1991	224	8.9	4.5 (3.9-5.0)
1992	203	8.1	4.0 (3.5-4.6)
1993	197	7.9	3.9 (3.3-4.4)
1994	245	9.8	4.8 (4.2-5.4)
1995	236	9.4	4.6 (4.0-5.2)
1996	110	4.4	2.1 (1.7-2.5)
1997	115	4.6	2.2 (1.8-2.6)
1998	163	6.5	3.2 (2.7-3.6)
1999	171	6.8	3.3 (2.8-3.8)
2000	152	6.1	2.9 (2.5-3.4)
2001	154	6.2	3.0 (2.5-3.4)
2002	147	5.9	2.8 (2.4-3.2)
2003	133	5.3	2.6 (2.1-3.0)
Intent of injury			
Unintentional	1099	43.9	1.5 (1.4-1.6)
Self-inflicted	541	21.6	0.8 (0.7-0.8)
Assault	627	25.0	0.9 (0.8-0.9)
Intent unknown	237	9.5	0.4 (0.3-0.4)

Table 4. Intent category for firearm-related injury in Finland in 1990-2003 (N=2504), by age and sex.

Characteristics	Intent category					
	Unintentional No. (%)	Self-inflicted	Assault No. (%)	Unknown No. (%)	All No. (%)	p-value
Sex						
Male	1005 (44.4)	510 (22.5)	536 (23.7)	215 (9.5)	2266 (100)	
Female	94 (39.5)	31 (13.0)	91 (38.2)	22 (9.5)	238 (100)	<0.001
Age (years)						
0-14	136 (76.4)	4 (2.2)	17 (9.6)	21 (11.8)	178 (100)	
15-24	312 (51.7)	94 (15.6)	132 (21.9)	66 (10.9)	604 (100)	
25-34	216 (57.3)	95 (16.4)	210 (36.3)	58 (10.0)	579 (100)	
35-44	176 (36.2)	126 (25.9)	143 (29.4)	41 (8.4)	486 (100)	
45-55	134 (37.7)	104 (29.3)	82 (23.1)	35 (9.9)	355 (100)	
>54	125 (41.4)	118 (39.1)	43 (14.2)	16 (5.3)	302 (100)	<0.001
All	1099 (100)	541 (100)	627 (100)	237 (100)	2504 (100)	
Year						
1990	138 (54.3)	52 (20.5)	46 (18.1)	18 (7.1)	254 (100)	
1991	116 (51.8)	42 (18.8)	41 (18.3)	25 (11.2)	224 (100)	
1992	102 (50.2)	33 (16.3)	51 (25.1)	17 (8.4)	203 (100)	
1993	96 (48.7)	37 (18.8)	38 (19.3)	26 (13.2)	197 (100)	
1994	115 (46.9)	40 (16.3)	65 (26.5)	25 (10.2)	245 (100)	
1995	107 (45.3)	48 (20.3)	60 (25.4)	21 (8.9)	236 (100)	
1996	56 (50.9)	19 (17.3)	27 (24.5)	8 (7.3)	110 (100)	
1997	53 (46.1)	32 (27.8)	23 (20.0)	7 (6.1)	115 (100)	
1998	67 (41.1)	40 (24.5)	43 (26.4)	13 (8.0)	163 (100)	
1999	68 (39.8)	45 (26.3)	40 (23.4)	18 (10.5)	171 (100)	
2000	45 (29.6)	37 (24.3)	52 (34.3)	18 (11.8)	152 (100)	
2001	50 (32.5)	35 (22.7)	53 (34.3)	16 (10.4)	154 (100)	
2002	41 (27.9)	40 (27.2)	51 (34.7)	15 (10.2)	147 (100)	
2003	45 (33.8)	41 (30.8)	37 (27.8)	10 (7.5)	133 (100)	<0.001
All	1099 (43.9)	541 (21.6)	627 (25.0)	237 (9.5)	2504 (100)	

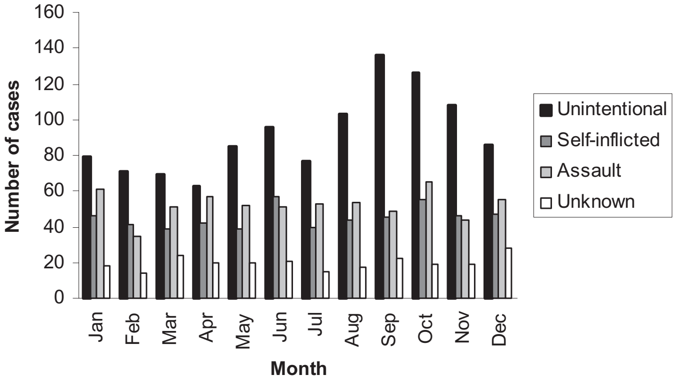

Figure 7. Numbers of firearm-related hospitalizations by month and intention in Finland between 1990 and 2003 (N=2504).

Gender, age, and annual distribution of the hospitalizations are shown in table 4. Men were victims in 91% of the incidences and their firearm-related injury hospitalization incidence rate was 10.0 times higher (95% CI: 8.8-11.4) than that of women's. The highest incidence rates were for persons between ages 15 and 24 and between 25 and 34, with rates of 6.9 (95% CI: 6.3-7.5) per 100 000 person-years and 6.0 (95% CI: 5.5-6.5), respectively (Table 6). The age of the injured people varied from under one year of age to 90 years and the mean age was 35.

A geographic variation was seen in incidence between the five university regions in Finland (Table 5), from 2.6 (95% CI 2.3-3.0) in the southwestern region of Turku to 4.2 (95% CI 3.8-4.6) found in the northern region of Oulu. This means that the relative risk of firearm-related injury was 1.6 (95% CI 1.4-1.8) times higher in the northern than the southwestern region.

Table 5. The incidence of firearm-related injury hospitalization by gross national product per capita and by University Region in Finland between 1990 and 2003 (N=2504)

University Region	Incidence (per 100 000 persons per year)	Gross National Product / Capita (U.S. $)
Oulu (OUR)	4.2 (95% CI: 3.8-4.6)	29 800
Kuopio (KUR)	4.2 (95% CI: 3.8-4.5)	27 300
Tampere (TaUR)	2.8 (95% CI: 2.5-3.0)	29 800
Turku (TuUR)	2.6 (95% CI: 2.3-3.0)	33 500
Helsinki (HUR)	3.1 (95% CI: 2.9-3.3)	47 300

Intention of injury

The intention category by sex and age is shown in in table 4. Unintentional injury dominated (76% of all) in the age group of 0–14-year-olds. The proportion of intentional injuries (self-inflicted and assault-related injuries) increased with age, being 53% in the over 54-year-olds group ($p<0.001$) (Table 4) . Unintentional injuries accounted for 54% of all firearm-related injuries in 1990, while the corresponding figure was 34% in 2003 ($p<0.001$). The overall decrease seen in the incidence of firearm-related injury hospitalizations was attributable to the decrease in unintentional injuries, because intentional injuries remained at the same level.

The head and the neck were the most common anatomic locations of firearm-related injuries, accounting for 35% of all injuries, followed by the lower limb (28%), the trunk (19%), and the upper limb (17%). The most common injury types were open wounds (54%) and fractures (14%). It became evident that fracture as an injury type increased its proportion of all injuries, and wounds declined in proportion with age. Children between under one year of age and 14 years sustained less fractures (5%) and more wounds (62%) than persons over 54 years, (24%) and (41%), respectively ($p<0.001$). Internal injuries (ICD-9 codes 860-869) required the longest time of hospitalization. The median length of hospitalization was three days, and it was significantly associated ($p<0.001$) with the type of injury but not with the patient's sex or the intent of injury.

1.2 Fatal injuries 1990–1999

According to the National Register of Deaths, there were 462 non-suicidal deaths caused by the use of firearms between 1990 and 1999. In nine cases, death had occurred abroad. In one case, the social security number had been incorrectly recorded and the death certificate for this individual could not be indentified and analyzed. Data for these 10 cases were excluded, thus a total of 452 cases were included in this study. Distributions of the nature of the shooting incidents and numbers of deaths annually during the decade, excluding fatalities from suicide, are shown in Figure 8.

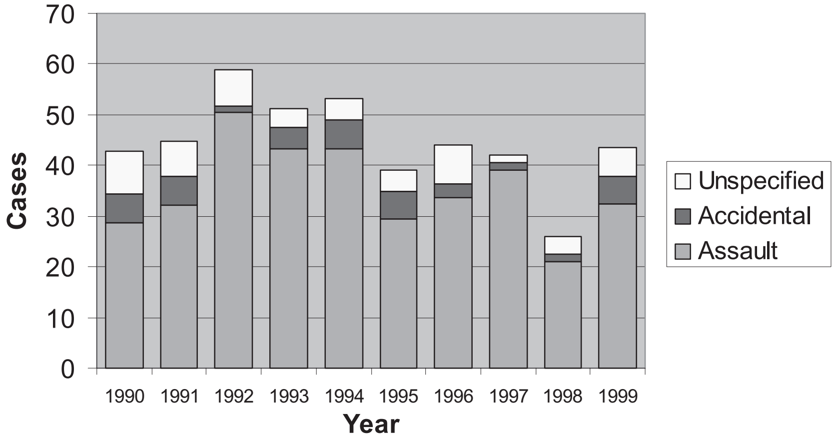

Figure 8. Distributions of the natures of shooting incidents and the numbers of deaths annually during the decade, excluding fatalities from suicide, from 1990 to 1999, by Mäkitie and Pihlajamäki (2002).

Of the 452 victims, 316 were male (70%), 136 female (30%). The mean age was 32 years. Most of the victims were civilians, but three policemen and two army conscripts died on duty.

The shooting had been violent in 351 cases (77.6%). Circumstances were unspecified in 58 (12.8%) cases. The shooting had been accidental in 43 cases (9.5%). Sixty-five victims (14.3%) were alive at hospital admittance (Table 6). In 38 of these 65 cases, the shooting had been violent.

The injury patterns varied in the two groups. Following violent shooting, the site of impact was the chest in 43% of the cases, the head in 42%, and the abdomen in 8%. Following accidental shootings, and when the circumstances had not been specified, the predominant site of injury was the head, in 68% of the cases. The injury site was the chest in 16% and the abdomen in 10% of the cases.

Despite the hospital care received, patients with chest injuries died on average 3 hours after admission to hospital. Patients with head injuries died on average after 13 hours in hospital. One patient with head injury, complicated by disorder of cerebrospinal fluid drainage and meningitis, died of pneumonia after 260 days in hospital. Half of the patients with abdominal injuries died after a few hours in hospital, the remainder after some weeks. There were minor differences in durations of hospital stay between the injury types (Table 6) .

Table 6. Profiles of 452 firearm-related deaths

Anatomic site of fatal injury	Death at the scene of the shooting (86 % of all cases)	Transported alive to hospital (14 % of all cases)	Average time (minimum and maximum), until death in hospital (hours)
Accidental shooting			
Head	19 (5 %)	6 (9 %)	15 (3-30)
Neck	2 (0.5 %)	1 (1.5 %)	2
Chest	7 (2 %)	1 (1.5 %)	4
Abdomen	3 (0.7 %)	2 (3 %)	2*
Extremities	1 (0.3 %)	–	–
Total	32 (8 %)	10 (15.5 %)	
Unspecified shooting			
Head	30 (8 %)	12 (18 %)	11 (2-30)**
Neck	1 (0.3 %)	1 (1.5 %)	22
Chest	7 (2 %)	1 (1.5 %)	2
Abdomen	2 (0.5 %)	3 (4.6 %)	6***
Extremities	–	–	–
Total	40 (10.5 %)	17 (26 %)	
Violent shooting			
Head	128 (33 %)	21 (32 %)	14 (1-72)
Neck	19 (5 %)	1 (1.5 %)	–****
Chest	148 (38 %)	4 (6 %)	4 (3-6)
Abdomen	18 (4.5 %)	11 (17 %)	3 (1-6)*****
Extremities	2 (0.5 %)	1 (1.5 %)	6
Total	315 (81.5 %)	38 (58.5 %)	
Grand total	387 (100 %)	65 (100 %)	

Exceptions: *17 days in one case, **260 days in one case, ***27 and 30 days in 2 cases, **** 16 days in one case, *****16, 25 and 55 days in 3 cases

Laboratory analyses revealed alcohol intake in 107 of the victims (30%) in the violence group and in 38 of the victims (38%) in the accidental or non-specified group. In 12 of the shooting cases in the violence group (3.3%) and in 2 in the accidental or non-specified (2%) group, the victims were noted to have taken illegal drugs (cannabis, an opiate, amphetamine).

Of the 65 patients (14%) admitted alive to hospital, 33 (51%) had been taken to a university hospital, 27 (41%) to a central hospital, and 5 (8%) to a regional hospital. Eighteen of the 21 hospital districts in Finland were involved.

2. Firearm Injuries of the Extremities

Gunshot fractures

In the study of gunshot fractures, a total of 36 patients with long bone fractures were identified. The incidence during the 5-year period was consequently estimated at five patients per 1 000 000 person-years. Sex distribution of this group of patients was 34 male and 2 female. The age of the victims varied between 19 and 79 years (mean, 34.4; SD, 12.21).

The etiology of trauma was accidental in 15 cases, an assault in 13, a suicidal attempt in 5, and unknown in 3 instances. The cause was self-inflicted in 14 cases, and alcohol abuse (overall percentage, 27.5%) was a usual reason for this.

Patients were admitted to hospital within a few hours of the injury. The wounding agent was a pistol in one-third, a rifle in one-third, and a shotgun in the remaining one-third of the cases. The shooting distance was point blank or only a few meters in 21 cases, between 50 and 200 meters in three cases, and unidentified (close?) in 12 cases.

All injuries except one were isolated, severe open fractures of type III without concomitant injuries.One patient suffered an injury to both legs. The fractures were subdivided into three types, type A (60%), type B (12.3%), and type C (27.7%). The location of injuries was the lower extremity in 22 cases and the upper in 14 cases. One-third of the fractures had moderate comminution and two-thirds had severe comminution.

Arterial lesions were present in ten patients (27.7%). The lesion was caused by shotgun (7), hunting rifle (2), or pistol (1). The injured arteries were femoral (1), anterior tibial (4), posterior tibial (1), peroneal (3), popliteal (3), brachial (2), and radial (1). Two patients had three arterial lesions in the same leg. Only three venous lesions were identified: two popliteal and one deep femoral (Table 7).

Table 7. Incidence of individual complications in 36 patients with long-bone fractures secondary to gunshot wounds

Complication	Number of patients
Injury-related	
Arterial lesion	10
Venous lesion	3
Damage to major nerve	7
Compartment syndrome	4
Joint lesion	2
None	16
Treatment-related	
Transient infection	15
Chronic osteitis	4
Delayed union	5
None	16

Nerves were injured in seven patients (19.4%). Two peroneus lesions, 4 medianus, 1 radialis, 1 ulnaris, and 1 brachialis were identified.

In two cases, an open injury of the knee joint was found evident. Considerable bone defects were caused in six cases (10 to 15 cm): four by shotguns and two by hunting rifles.

Debridement was performed successfully in two-thirds of the wounds. In nine cases, it was insufficient or followed by repeated revisions and wound infections. There were three large wounds where revision was neglected or forgotten. Delayed primary closure was performed in 5 to 7 days in the same two-thirds group as revision. Four patients needed skin grafting. Almost one-third of the wounds were, however, closed primarily and most of them became infected afterwards.

Fasciotomy was not performed routinely was insufficient in six leg wounds and in one forearm wound. Four patients contracted compartment syndrome. Small or avascular, unattached fragments were removed. The arteries were repaired by end-to-end anastomosis or a vein patch graft. One short popliteal artery defect was reconstructed successfully by using prosthesis. Two vein injuries were repaired by lateral suture (Table 8). No attempted primary nerve reconstruction was attempted. Only one late reconstruction was recorded. The knee joint injuries were revised, closed, and a suction drainage was applied.

Table 8. Repair of 18 vascular lesions

Lesion	Method
Arteries	
Superficial femoral	Vein graft
Popliteal (2)	Vein graft
Popliteal	Prosthesis
Anterior tibial (2)	End-to-end
Anterior tibial (2)	Vein graft
Posterior tibial	Vein graft
Peroneal (2)	Vein graft
Peroneal	End-to-end
Brachial	Vein graft
Brachial	End-to-end
Radial	End-to-end
Veins	
Deep femoral	Vein graft
Popliteal (2)	Lateral suture

Fractures were immobilized by external fixation (Hoffmann) in about two-thirds of the patients. Primary internal fixation by a locking nail was used in four cases. Primary bone grafting was tried on other four fractures. Six patients were treated by plaster of Paris immobilization and two by skeletal traction. Local transposition flaps and microvascular flaps were needed afterwards in six cases.

Primary antimicrobial therapy was started by intravenous benzylpenicillin (30%), cloxacillin (40%), cefuroxin (20%), and unreported (10%). No statistical difference between use of antimicrobials and infection rate was noticed. Clinical evidence of wound infection was documented in the records of 15 patients (41.4%), including pin tract infections (22%). The tibia and the femur were the most frequent sites involved, accounting for 13 infections, with only two located in the upper extremity. Two patients had septicemia and four chronic osteomyelitis.

Bone consolidation was completed normally in two-thirds of the fractures. The rest had delayed union (5) or nonunion (6). One above-knee amputation was unavoidable after unsuccessful treatment.

The average initial stay in hospital depended on the weapon in question: length of stay for those with pistol wounds 15 days, with rifle wounds 31 days, and with shotgun wounds 35.5 days. The stay was followed by 2 to 4, or more post-treatment periods, and a number of reconstructive operations in some of the most severe cases.

Vascular injuries

This series material of extremital gunshot injuries from the period of 1990–1999 consisted of 25 males and 7 females. The mean age was 32.8 years (17–68 years). The incidence was 6.0 (CI: 4.1–8.5) per 10 000 000 person-years and did not change significantly during the period. Patients were treated in 16 central and two district hospitals of the 21 hospital districts in the country. The average hospitalization period of the primary hospital stay (28 patients) was 13.5 days. In many cases, the follow-up hospitalization took place in a district or a psychiatric hospital. In the few cases needing amputation, the primary hospitalization period was 17.4 days.

The shooting was unintentional in 14 cases, violence-related in 11 cases (including an attempt at self-damage in two cases and a consequence of legal interference by police in two cases) and unclear in 7 cases. The weapon used was shotgun in 12, pistol in 10, hunting rifle in 3, assault rifle in 1, airgun in 1, and an unknown hand weapon in 5 cases.

Alcohol and illegal drug and substance use were strongly related to vascular gunshot wounds in this material, since altogether 13 victims (41%) were under the influence of alcohol or drugs. Ten (31%) of them were under the influence of alcohol at the time of shooting, but drug and substance use (cannabis, heroin, amphetamine) was almost equally common and mentioned in the records of seven cases (22%).

Altogether, 43 severe vascular lesions were identified. Anatomically, the injuries mostly affected the vessels in the lower extremities (38 lesions) while only five lesions were located in the upper extremities (Table 9). Four arterial-venous fistulas were detected with six concurrent gunshot fractures involving a severe vascular injury. Associated arterial and venous trauma was evident in ten cases. The most common combination, found in a total of six cases, was an injury in the femoral artery and an injury in the femoral vein or in the great saphenous vein.

Table 9. Location of 43 vascular lesions in 32 patients. Fatal lesions located in the femoral and popliteal arteries.

Arteries and Veins	Number of lesions
Femoral artery	6
Popliteal artery	6
Superficial femoral artery	5
Anterior tibial artery	4
Posterior tibial artery	4
Axillary artery	2
Radial artery	1
External iliac artery	1
Deep femoral artery	1
Great saphenous vein	5
Femoral vein	2
Superficial femoral vein	2
Popliteal vein	2
Axillary vein	1
Tibial vein	1
Total	43

The use of a tourniquet during the initial treatment was mentioned in four cases. Seven of the injured had suffered from a haemodynamic shock (systolic pressure under 90mm Hg) during the initial treatment procedures.

Ten patients (36%) were primarily treated by vascular surgeons. Reviewing the hospital records implied substantial clinical variation. Two synthetic prostheses and 12 great saphenous vein grafts were used. After primary vascular reconstruction, five patients (18%) required reoperations to establish adequate permanent distal perfusion. In both cases with synthetic prosthesis used, the synthetic graft failed. Replacement of the prosthesis was due to a septic infection in one case and difficulties in closure of the primary wound in the other case. In the three other cases, the primary repair needed reoperation due to various problems (Table 10). After the reoperations, no further acute problems were encountered.

Five amputations were performed as the primary surgical treatment. In two cases a reconstruction was impossible due to extensive vascular and tissue destruction, in one case the patient was severely multi-injured, in one case a coronary disease was complicating the treatment, and in one case an amputation of the thigh was performed as a life-saving procedure due to unstable hypovolemic shock (Table 11). No late amputations were performed.

The weapon used did not play any coherent role when comparing different vascular lesions in this study.

Table 10. Details of five cases with vascular reoperations. (PTFE = synthetic polytetrafluroethylene graft, SVG = autogenous saphenous vein graft).

Sex and age	Weapon	Vessels injured	Primary reconstruction	First re-operation	Second re-operation
Male, 36	Shotgun	Femoral artery and vein	The artery and vein repaired by PTFEs.	The failed PTFE in artery replaced by SVG.	The failed SVG in artery repaired by a new SVG.
Male, 21	Air-rifle	Superficial femoral artery and femoral vein	The A-V fistula closed by an endoprothesis stent.	The unclosed A-V fistula closed by ligation.	
Male, 18	Shotgun	Superficial femoral artery and femoral vein	The artery repaired by SVG and the vein by ligation.	The SVG replaced by a new SVG due to inadequate distal perfusion.	
Male, 42	Pistol	Popliteal artery and vein	The artery repaired by PTFE and the vein by ligation.	Failed PTLE repaired by SVG.	
Male, 26	Shotgun	Popliteal artery and femoral vein	The artery repaired by SVG and the vein by ligation.	Re-exploration and ligation of the bleeding branches of popliteal artery.	

Table 11. Details of amputations after civilian gunshot injuries in Finland, 1990 to 1999.

Sex and age	Weapon	Vessels injured and associated trauma	Main indication for amputation	Level of amputation
Male, 18	Unknown	External iliac artery and deformation of thigh.	Unstable hypovolemic shock. Amputation done as lifesaving procedure.	Thigh
Male, 68	Shotgun	Anterior tibial artery and fracture of leg.	Reconstruction not possible due to coronary disease. A re-amputation and hemostasis was needed for post-operative bleeding.	Lower leg
Female, 30	Shotgun	Anterior tibial artery. Gustilo gradus III c injury.	Reconstruction not possible and a delay of transportation.	Lower leg
Female, 42	Shotgun	Extensive tissue destruction of forearm	Reconstruction not possible due to tissue loss.	Brachial arm
Female, 42	Shotgun	Extensive tissue destruction of forearm	Reconstruction not possible due to tissue loss and other multiple injuries.	Forearm

3. Epidemiology of Explosion Injuries

3.1 Hospitalizations 1991–1995

There were altogether 507 accidents, 2,0 events per 100 000 person-years, due to explosions. In 68 (13%) cases, the explosion resulted from pressure vessels, in 127 (25%) cases from explosives, in 146 (29%) cases from fireworks, and in 166 (32%) cases from accidents associated with unspecified explosions. In addition, 14 persons died at the scene, during transportation or in the hospital.

Of the survivors, 445 (90%) were men and 48 (10%) women. The average age was 30 years, 45 years in men and 29 years in women. Injuries comprised soft tissue wounds in 148 (26%) cases, burn injuries in 144 (25%) cases, sensory organ deficits in 132 (23%) cases, crush injuries and traumatic amputations in 179 (14%) and fractures 56 (19%) cases (Table 12). The soft tissue injuries were mainly various lacerations and scratches. In 30% of the upper extremity wounds, tendon repair surgery was performed. There were 120 eye injuries. The most critical of the trunk injuries were two intestinal perforations and one cardiac contusion.

Examination of the duration of hospital stay hospitalization showed that 72% of the patients stayed in hospital for one day only, 15,4% stayed for two, and 12,4% stayed for three or more days. The shortest duration was one day and the longest 165 days, the average in-patient time being 11,4 days. The total number of hospital days used for treatment of explosion-related injuries from 1991 to 1995 was 5460.

3.2 Fatal injuries 1985–2004

For the period 1985–2004, the National Register of Deaths contained altogether 64 unintentional or unspecific deaths resulting from explosions. In three cases, death had occurred abroad. Data of these three cases were excluded. In addition, the number of homicides was 7, the result of a home made bomb assault and a car bomb in 2002, thus rendering 68 cases eligible for this study. Explosion-related homicides were not found from other years. The causes of explosion indicated explosives in 20 cases, unclear explosion in 8 cases, electric fuse in 6 cases, and explosion of gasoline in 2 cases. The electric fuse in most of the cases referred to suicides where the fuse exploded in the mouth. Annually, the number of explosion-related deaths varied from one to 14. A notable incident occurred in 2002, when six people died in a terrorist explosion, committed for unidentified reasons with a homemade bomb in a suburban shopping center. Another bomb related assault took place in the same year, with one victim dead. Distributions of the natures of the explosion incidents and the numbers of deaths are shown in Figure 9.

Table 12. Anatomical region and causative agents of explosion injuries in Finland from 1991 to 1995. Total of 570 separate injuries in 493 hospitalized patients.

	Pressure vessel	Firework	Explosive	Unspecified	Total
Fractures:					56
- upper extremity	9	11	6	8	
- lower extremity	5	3	3	1	
- head	1			9	
Ear and eye:					132
- eye injury	10	16	54	40	
- ear injury	1	2	6	3	
Crush and traumatic amputations:					79
- upper extremity	5	27	26	20	
- lower extremity	1				
Wounds and lacerations:					148
- head	2	3	5	1	
- trunk	2	4	4	4	
- upper extremity	10	33	28	30	
- lower extremity	10	8	1	3	
Burns:					144
- head	9	8	11	18	
- trunk	5	5	1	7	
- upper extremity	12	6	14	16	
- lower extremity	2	2	2	3	
- multiple areas	4	1	1	15	
- respiratory tracts	1	1			
Neurological areas:					11
- cerebral concussion		1		3	
- cerebral contusion				1	
- epidural bleed				1	
- peripheral nerve injury	4			1	
Total	93	131	162	183	570

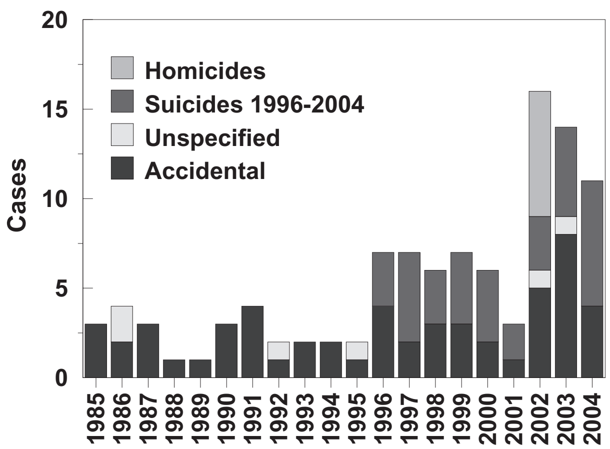

Figure 9. Annual numbers of explosion-related deaths and natures of incidents from 1985 to 2004. Suicides are shown from 1996 to 2004.

Of the 19 patients (28%) admitted alive to hospital, eleven (58%) had been taken to a university hospital and 8 (42%) to a central hospital. Eight of the first mentioned patients, many of them suffering massive burns, were transferred to the Helsinki University Hospital. In victims receiving hospital treatment, the nature of injuries showed wide variation, but information about initial treatments was unavailable (Table 13). Laboratory analysis revealed alcohol intake in 8 of the victims (12%) of the unintentional cases and in 36% of the suicides.

Table 13. **Causes and profiles of fatal explosion injuries in Finland from 1985 to 2004, suici exclusive.**

Cause of explosion	Death on scene of explosion	Main fatal injuries at the scene	Transported alive to hospitals	Main injuries in emergency departments	Average time (minimum and maximum) until death in hospital (hours)
Explosives	10	Massive lacerations, ruptures of main vessels.	3	Fractures of the cranium. Traumatic amputations. Lacerations of the trunk.	20 h (1-38)
Homemade bomb	8	Massive lacerations. Multiple penetrating injuries.	3	Lacerations. Multiple penetrating injuries.	3 (1-6)
Pressured tire or tube	7	Injury and fracture of the head and trunk.	2	Fractures and injuries of the cranium and brains.	1½ (1-2)
Gas	5	Massive burns, fracture of the cranium.	1	Massive burns.	14 days
Dust or vapor cloud inside halls	5	Fractures and injuries of the cranium. Carbon monoxide poisoning. Massive burns.	2	Massive burns.	6, *
Boiler	4	Massive burns. Exposure to heat.	2	Massive intra-abdominal haemorrhages, massive burns.	2 h, **
Pressured devices	3	Haemorrhages and fractures. Blast injury.	1	Contusion and haemorrhages of the legs.	3
Explosion of barrel or tank	3	Massive burns. Fractures and contusions of the cranium.	1	ARDS and massive burns.	19 days
Gas bottle	1	Massive burns.	3	Massive burns.	5 days (1-10 days)
Fireworks	2	Haemorrhages, haemothorax.	1	Massive burns.	36
Explosion of a glue barrel	1	Fractures and contusion of the cranium.			
TOTAL (68)	49 (72%)		19 (28%)		

Exceptions: * 18 days in one case, ** 7 days in one case

General Discussion

This study showed that civilian, unintentional firearm injuries have decreased during the nearly 20-year study period. However, the incidence of intentional injuries as well as the incidence of fatal firearm injuries have remained unaltered. Rare fatal explosion injuries have slightly increased. However, the prevalence of ballistic traumas in Finland is stable.

In Finland, only few epidemiologic studies on ballistic trauma have been published and in many European countries, the situation is the same. However, it is important to be aware of whether firearm or explosion-related violence and its severity is increasing or not. Protection of the society against terrorism and against the related assaults, including terrorist-induced explosions, is undoubtedly one significant challenge to be addressed by the authorities responsible for our national security.

Firearm injuries

The present study pointed out that gunshot injuries cannot have been considered a negligible medical problem in Finland in the late 1980s. The treatment of firearm injuries was found to require approximately 3300 hospital days in the country annually. However, the absolute number as well as the incidence of firearm-related hospitalizations declined in Finland between 1990 and 2003. The decline was due to the decreasing number of unintentional injuries. This is a noteworthy phenomenon when comparing to foreign studies reporting on the increasing significance of these injuries (e.g. Annest et al. 1995, WHO 2001). The incidence level of hospitalizations due to intentional firearm-related injuries remained unaltered in Finland. Men aged 15 to 34 years had the highest incidence rates of firearm-related injuries. Unfortunately, no studies have been conducted in the country with the aim to assess the degree of permanent disability sustained by patients studied here.

Injury rates in the United States are non-comparable to those of Europe (Annest et al. 1995, Cherry et al. 1998, Cheng et al. 2001). The two continents have their own, long cultural, ethnic, economic, and political history affecting almost every aspect of life, including medicine. The overall incidence rates in Finland are equal to one-third of the incidence rates seen among the white population of California (Vassar and Kizer 1996), and one-tenth of the overall incidence in the entire United States (Annest et al. 1995). Another significant difference existed between Finland and the Unites States: unintentional injuries were dominant in our study, while the majority of firearm-related injuries in the United States were intentional (Cherry et al. 1998, Krug et al. 1998). Similarities can be found as well. Young men have the highest hospitalization rates in Finland, United States and New Zealand (Annest et al. 1995, Langley 1996).

While the incidence of unintentional injuries in our country decreased, that of intentional injuries remained unaltered over the study period. There is no reason to assume that the varying policies in hospitalization or the differences in the political climate or legislation might have changed over the study period and influenced this development. Indeed, the reason for the decline seen in the incidence of unintentional injuries remained unclear and calls for further studies.

An interesting finding in our study was that the median hospitalization time of the first recorded admission was the same regardless whether the injury was unintentional or intentional. This suggests that unintentional injuries were as severe as intentional injuries.

Another noteworthy finding, which has escaped wide attention in Finland, was the high number of unintentional firearm-related injuries occurring during the months of September and October. Since there are approximately 300 000 recreational hunters in Finland and since autumn is the most popular hunting season in the country, it could be speculated that these hospitalizations are due to hunting-related unintentional injuries, i.e. injury risk. Research is needed to identify whether these injuries really are hunting-related and in what sort of circumstances they occur. Yet another interesting finding was that the risk of firearm-related injury hospitalization is higher in the northern than in the southern Finland.

Before performing the series of present studies, there existed a deficiency on national information about the specific features related to fatal non-suicidal firearm injuries. The study presented here showed that the annual incidences of fatal non-suicidal firearm injuries did not change significantly in Finland between 1990 and 1999, though a general increase in violence has been reported in the country (Streng et al. 2001). The victims of such injuries required minimal hospital resources, because most died at the scene of the shooting.

In the United States, it has been estimated that there are five non-fatal gunshot injuries for each death (Lee et al. 1991, Nelson et al. 1987). In Finland, the ratio was close to 1:1, probably partly because only the patients requiring in-patient treatment were recorded. Another explanation seems to be the high proportion of suicides committed, increasing the prehospital mortality in Finland. Of those fatally injured and admitted alive to hospital, most died within 24 hours of admission. Previous Finnish population-based investigations have shown that those who survive truncal firearm injuries spend on average 12 to 16 days in hospital (Leppäniemi et al 1996, Streng et al. 2001).

In Finland, about 250 individuals are annually hospitalized on account of shooting injuries (Streng et al. 2001). The patients in the study III, brought to hospital alive, therefore represented some 2% of all patients annually hospitalized due to a firearm injury. The overall hospital mortality from truncal gunshot wounds in Finland has been documented as 2% (Streng et al. 2001). The corresponding mortality rate from shooting as a means of attempting suicide in Finland has been reported to be 10%. In some urban areas in the USA, 5% of the victims of firearm injuries brought to a hospital emergency department could not be resuscitated (Kellerman et al. 1996).

It has been suggested that restricting the availability of firerms might be one way of minimizing firearm injuries related to violence and suicide (Streng et al. 2001, Lester 1990). In the Unites States, one of the key challenges in devising a system for monitoring firearm-related injuries appears to be the identification of effective techniques for linking health data with other information (Mercy et al. 1998). The aim in Finland, however, is to reduce the high, albeit stabile, incidence of firearm deaths.

The extremities accounted for 45% of all non-fatal firearm injuries in the country, most of the extremital injuries being soft tissue injuries. This study specifically focused on complicated fractures because of the importance of concomitant soft tissue injuries. Despite the shortness of the study period and the rarity of extremital gunshot fractures, the findings were of clinical value. Moreover, there is still great controversy about the treatment of this type of severe fractures.

The results of this study indicated that a comprehensive, war surgical approach to civilian gunshot fractures in the country can be supported for the following reasons:

1. Firing from short ranges often causes massive tissue destruction.
2. Adequate revision surgery is mandatory.
3. External fixation seems to be the method of choice in severe gunshot wounds with extensive bone and periosteal loss. Satisfactory fixation contributes to the healing of soft tissues.
4. Some complications are likely to be avoided if the principles of surgery for war victims have been learned, kept in mind, and complied with.

In this study, vascular gunshot injuries of the extremities were not common, accounting for approximately only two per cent of all gunshot injury hospitalizations in the country. Moreover, injuries studied represented approximately five per cent of the vascular traumas reported in the country during the same decade (Fingerhut et al. 2002). In most cases, the trauma mechanism of vascular injuries in Finland has been iatrogenic or penetrating, and stab wounds have been more common than gunshot wounds (Fingerhut et al. 2002). In 41% of the cases studied here, a very strong association emerged between alcohol or drug use and the injury incidents studied as well as other gunshot incidents.

In Finland, the incidence of reoperations after vascular gunshot injury was 18%. In a series of 31 patients with vascular shotgun injuries from the United States, five patients (16%) needed reoperations after primary surgery (Roberts and String 1984). In a South African series, twenty one (12%) of 169 injured patients underwent an unsuccessful vascular operation and all, except one, were re-explored (Degiannis et al. 1995). McHenry and co-workers reported on 27 patients from the United States, treated for fractures with major vascular injuries with no cases of disruption by any method of revascularization (McHenry et al. 2002).

The patients with gunshot injuries to the extremities were treated at university and central hospital emergency departments, by general surgeons in smaller hospitals and orthopaedic, plastic or vascular surgeons in larger hospitals. The severity of wounds and primary operative approach in management varied. Injuries studied here were rarities and as such challenges for surgeons on call. The small population density and the relatively large geographic area of Finland do not favor high volume, centralized trauma management systems, which is reflected in the small material presented here.

Explosion injuries

Considering the epidemiologic aspect, explosion injuries requiring hospitalization or resulting in death were not a great problem in Finland in the 1990s. Of the explosion injuries examined in the 1990s, injuries to the extremities and the eyes were dominant. In 1992, injuries represented only 0,2% of the treatment periods and 0,1% of the hospital bed-days in the country. The national incidence of explosion traumas studied appears to be stabile. A slight increase of injuries from fireworks was noted from the early 1990s. The possible reason may be the decreased prices of fireworks together with the lowered requirements to obtain New Year's Eve fireworks permits in the 1990s. Annually, there were on average seven explosion-related deaths in the country. However, over a two-year period from 2001, a slight increase in the deaths, mainly based on two homemade bomb attacks, was noticed.

In the United States, there were 12 216 bombing incidents just between 1980 and 1990. This trend continued during the 1990s, with 1582 bombings causing 222 injuries and 27 deaths in the United States in 1990 alone (Frykberg 2002).

In explosion accidents, energy release was high and fatal injuries were common, frequently the death was immediate. Medical findings were as expected. When comparing results reported here to the previous Finnish studies, explosion injuries proved fatal in 3% of boiler explosions, in 1% of explosions involving explosives, and in 1% of explosions involving fireworks, which indicates that the most dangerous explosions in civilian accidents were related to boilers.

Substantial attention has been directed at developing methods for explosion injury prevention. The information obtained from the present study would emphasize the usefulness of strict laws regulating the use of explosives enforced together with preventive methods. Furthermore, in many countries, Finland inclusive, research has focused on protective equipment. These efforts face several problems as the effects of blasts detonated at a close range are difficult to counteract (Barss et al 1998, Lehkonen et al. 1999, Robertson 1998).

Discoveries arising from studies on injury epidemiology and pathology, such as the most severe explosion injuries here, may lead to improvements in safety technologies and trauma care (Winston et al. 1996). In case of Finland, the fortunate situation of the small number of explosion injuries may be attributable to the strict laws regulating the use of explosives and pressure vessels, as well as to the emphasis laid on occupational health and safety issues in general.

Strengths and weaknesses of the study

The first step in any reseach project is to ask a question or state a hypothesis that defines the objective of the study, which, in turn, determines the material and method needed (Robertson 1998). In this thesis, the data comprised nationwide material based on all papers presented here. In addition to firearm- and explosion-injuries, there was a special interest in extremital injuries. Even very limited descriptive studies (Studies IV and V) offer the opportunity to examine or collect data on the various aspects of an injury; characteristics and behavior of persons injured or others at the scene, places of occurrence, circumstances, injury management, and costs of treatment (Robertson 1998).

The long study period and nationwide data constituted a strength of the present study. The nationwide registers, the National Hospital Discharge Register and the Cause-of-Death Register, have shown to be accurate and complete (Official Statistics 2003, Kannus et al. 1999, Keskitalo and Aro 1991, Salmela and Koistinen 1987). Second, due to the personal identification number, it was possible to follow the patients during the study period and thus order and review all personal records from hospitals for each patient. A weakness of the study is the possibility that data on some individual patients may have been registered twice, for example, at the turn of the year. It is also possible that the E-codes, and other codes belonging to the "external causes" group, have in some individual cases not been properly registered, in which case the codes were unavailable for the register search.

An important issue addressed in this study is the significance of injury severity measurements when investigating injuries or considering injury control effects. The impact of prevention or treatment on deaths should be measured in terms of the potential years of lives lost or preserved, and the years of disability avoided, yet such statistics are rarely seen in medical and public health literature (Robertson 1998). Hopefully, issues of this kind are the next steps for Finnish studies on firearm and explosion epidemiology as research issues of this nature were not included in this study. Moreover, no studies have been conducted in Finland to assess the degree of permanent disability sustained by patients studied here.

Medical records, augmented by death certificates and coroner's or medical examiner's records of deaths from injury, are the best sources for case identification for most studies.

Although many such records do not contain data on the circumstances of injury and other variables, they usually provide information on the characteristics of the injury and its severity (Robertson 1998).

The availability of reliable health statistics is generally a reflection of the country's development level (Barss 1998). Even in developed countries, death certificates typically lack details of the circumstances and the contributing factors, such as alcohol consumption (Barss 1998).

Preventive strategies

Understanding and control of injuries have been delayed, both because the causes of injuries are often multifactorial and because prevention may require multisectoral intervention (Barss 1998). Adoption of any one strategy is dependent on various aspects of ideology, politics, and cost efficiency. Epidemiologists can play a central role in pinpointing energy exposures, incidence, and severity of injuries among particular populations and in evaluation of the effectiveness of injury control strategies. Costs of injury control can be minimized by targeting strategies to agents, vehicles or vectors, hosts, and environments in which the severity of injuries and their associated costs are most acute (Robertson 1998).

There are two reasons, hospitalization and death, for drawing attention to severe injuries only. First, large numbers of minor cuts, bruises, abrasions, and the like occur in circumstances that are essentially different from the severe (Rice and MacKenzie 1989). The attempts to control the most frequent injuries will merely serve to misdirect resources from the most severe and money consuming. Second, the costs of data collection are remarkably reduced by limiting it to hospitalized and fatal injuries (Robertson 1998).

Implementation of injury prevention strategies in society can be undertaken through three primary modalities: (a) legislation and enforcement, (b) education and behavior change, and (c) engineering and technology.

Enforcement and legislation can be generated on different governmental levels. Educational and behavioral changes were once the mainstay of injury prevention work. However, if used uncritically and without evaluation, they usual produce a limited effect (MacKenzie and Fowler 2004). Engineering and technology address a variety of issues, such as development of safer roadways, more effective safety features for automobiles, and more sophisticated protection systems required for manufacturing equipment. These three main modalities are frequently complementary (MacKenzie and Fowler 2004). No doubt, the main modalities are applied to firearms, hunting, and shooting ranges.

Occasionally, there arises a need to organize several groups with different interests into a coalition focusing on one particular injury prevention goal. Such groups might include govermental agencies, such as the health department, schools and academic institutions, as well as media, community groups, private foundations, and medical associations (Brown et al. 1990).

A critical element of injury prevention programs, and one which is frequently given inadequate attention, is the evaluation of effectiveness. The main goal of such evaluation is to provide feedback for modification of the intervention (MacKenzie and Fowler 2004)

Given a priority to reduce deaths and severe injuries, and considering the often versatile circumstances that contribute to severe and nonsevere injuries, allocation of resources to collection of more detailed data on less severe injuries would be difficult to justify. Exceptions may occur in work or other settings where less severe injuries, like musculoskeletal injuries, can result in inability to work (Robertson 1998).

The goal of a prevention-oriented research project is to specify the extent to which injury severity would be reduced by changing a given factor hypothesized to contribute to the injury or severity, other things being equal (Robertson 1998). In general, high-risk groups, hazardous equipment and environmental factors, and dangerous activities can be identified (Barss 1998). Alcohol is associated with many types of unintentional and intentional injuries (Jones et al. 1992). In Finland, a close association between alcohol use and ballistic trauma was verified in the present studies.

The results of several studies have demonstrated that the prevention of firearm injuries is difficult (Cassel et al. 1998, Dummings and Koepsell 1998), despite the extensive literature available on the subject. The large number of firearm-related suicides is typical of Finland. Risk factors that influence injuries caused by small arms can be separated into four general categories (Kellerman 1998):

- factors that influence the use of small arms over other possible weapon choices
- factors that influence interpersonal violence
- factors that influence self-directed violence (i.e. suicide)
- factors that influence collective violence.

It is important to recognize that communities with different gun laws, and the resultant differences in the prevalence of gun ownership, also demonstrate decreases in homicide rates compared to communities with more restrictive gun control laws (Sloan et al 1988). Data on the effects of imposing more restrictive gun ownership laws in a given area over time is less clear (MacKenzie and Fowler 2004). The weight of the evidence does indicate, however, a net reduction in firearm-related deaths from such laws (Rivara et al. 1997, Loftin et al. 1991).

A dramatic reduction in the overall firearm-related deaths and particularly suicides by firearms occurred in Australia after a reform of firearms legislation (Ozanne-Smith et al. 2004). This unique study could be a source of much innovation also in Finland. The author would like to propose similar licencing schemes to Finland. Furthermore, the idea that a central criterion for obtaining a gun permit would be a completed military service is recommendable, because, in Finland's compulsory military service, 80% of the male population are guaranteed a thorough and safe training in the use of guns (Mäkitie et al. 1995).

Other preventive measures directed at firearms include educational programs to teach safe gun handling, primarily with the aim to decrease unintentional firearm injuries. However, similar to other generic nonfocused educational programs, the efficacy of such programs has not been well demonstrated (MacKenzie and Fowler 2004).

In Finland, activities, such as education and counseling, could be planned for recreational firearm users in order to reduce firearm-related injuries. Since hunting licences and hunting examinations are compulsory for all recreational hunters in Finland, firearm safety education could easily be arranged in connection with hunting examinations in order to decrease the number of hunting-related injuries.

The public health sector with its capacity to scientifically evaluate available information offers a more systematic and better informed standpoint on which to build and develop policy and programming regarding small arms prevention and control. This is especially important given the emotionally and ideologically charged debates about issues such as gun ownership and curbing the arms trade (WHO 2001).

The results of the study presented here might contribute to planning prevention strategies for explosion incidents, initial treatment strategies, or even ideas for protective equipment. However, severe explosion injuries seem to represent a minor problem in our national trauma centers. An important individual factor in the prevention of explosion-related deaths is to improve the safety of boiler use and fireworks. It has also been shown that planning protection against explosion-related injuries remains difficult (Mäkitie and Lamberg 2000).

There are numerous trends in trauma prevention – many of them not mentioned in the present study – which can lead us towards a better understanding of trauma as a phenomenon and, by extension, improve preventive strategies. In the fight against firearm and explosion injuries in Finland, setting the focus on the task through "thinking globally and acting locally" (Leppäniemi 2004) seems to be creditable. Since it has been suggested that restricting the availability of firearms might be one way of minimizing firearm injuries related to violence and suicide (Lester 1990), an ultimate motion could be a denial of legal permission for purchasing or possessing firearms.

Conclusions

Recalling the aims of the study and the initial problems, the results can be summarized in the following conclusions:

1. The total incidence of firearm-related injuries in Finland has decreased from 5.1 cases per 100 000 person-years from the late 1980s to 2.6 cases per 100 000 person-years in 2003. The median length of hospitalization was three days and the length was significantly associated with the injury type. The longest hospitalizations were due to rare internal injuries. Although these injuries do not represent a major cause of morbidity among Finns, they cannot be considered as a negligible medical problem in the country.
2. The annual incidence, 1.8 cases per 100 000 person-years, of fatal non-suicidal firearm injuries was low and it did not change significantly in Finland between 1990 and 1999. The victims of such injuries required minimal hospital resources, because most died at the scene of the shooting. Compared to non-suicidal deaths, the number of firearm-related suicides was almost eight times higher.
3. Severe firearm injuries of the extremities were rare, less than 0.1 cases per 100 000 person-years. Some complications in fracture management may be avoided if war surgical principles are followed. The proportion of reoperations, amputations and lengthy hospitalization stays was noteworthy in cases of severe vascular gunshot injuries of the extremities.
4. Epidemiologically, non-fatal explosion injuries (2.0 cases per 100 000 person-years) are not a great problem in the country in comparison to all accidents, but their medical significance should not be underestimated.
5. Unintentional and intentional explosion-related deaths are rarities in the country. It is worth consideration, however, that a slight rise in the mortality rate was evident over the 20-year period of this study.
6. Overall, the efforts in the Finnish legislation and the national prevention strategies concerning the ballistic injuries studied, should be aknowledged as commendable. This study directs attention to the necessity of future programs for

- preventing the potentially lethal combination of alcohol and drug or substance abuse and firearms and explosives
- organizing vigorous educational measures and interventions aimed at recreational users of firearms and pyrotechnics, and
- initiating re-evaluation and possible reform of the legal requirements for granting licenses for firearms in Finland.

Challenges for the Future

Given that the study was the first ever extensive report describing the occurrence and nature of firearm- and explosion-injuries in Finland, many important etiologic aspects still remain unclear.

As previously described, the Cause-of-Death Register and the National Hospital Discharge Register are accurate, but the lack of high-quality, firearm-related violence and injury behavior reports is remarkable in Finland. Although the use of firearms is not a great public problem, the effort to identify and reduce their use should be continuously promoted.

The main findings of this study indicated that intentional or unintentional firearm-related injuries are not common. Suicides by firearms, however, continue to present a serious problem in the country. To counteract this problem, an extensive program against suicides has just been completed in the country. With the exception of one major attack in 2002, intentional use of explosives has been insignificant in the country. Reducing explosion injuries should indeed focus on practical safety features, such as the safe use of boilers and fireworks.

Important collaboration has taken place, involving the trauma centers and the Finnish Police as well as the Finnish Defense Forces. There, however, the main focus has been on tactical medicine in emergency firearm situations. The author would like to suggest providing more realistic information of the consequences of firearms and firearm-related injuries for adolescents. Such an initiative would contribute to the prevention of the use of firearms, an issue that has not been widely discussed in schools or in various health education programs.

There is no doubt that many of the risk factors for firearm injuries identified can not be erased, instead they will survive to be encountered in the near future. The challenge for future observations is to continuously explore the causal relations between the risk factors and injuries, with a special 'firearm' aim to locate such causal risk factors that can be modified to reduce injuries in general, and firearm injuries in particular.

In Finland, principles of war surgery are well known to military surgeons participating in the International Committee of the Red Cross missions, and those treating refugees with war wounds. In the Logistic Training Center of the Finnish Defense Forces, experimental war surgery has been taught for many years at reserve medical officer courses. The Medical Section of the Defense Staff have published a textbook on field surgery and medicine (authored by one hundred and eleven specialists) that contains war surgical methods in detail (Koskenvuo Medical Section 1993). Education of young civilian surgeons in war surgery started in 1998. In the future, excellent treatment results could be expected.

Based on the high proportion of deaths occurring in prehospital settings, the author has emphasized the importance of prevention concerning the injuries studied. Alcohol is associated with many types of unintentional and intentional injuries (Jones et al.

1992). Controlling the sale, advertising, and use of alcohol in a country should be a high priority for any injury control program (Barss 1998). Finnish alcohol legislation underwent a change in 2004 toward reducing the taxes and prices of alcohol. In the studies reported here, there was a strong influence of alcohol observed among approximately one-third of all cases. Since alcohol was strongly related to intentional injuries, violence, and suicides, it will be important to investigate how alcohol consumption in the country could be diminished. The author is aware that this is a controversial subject, since alcohol legislation has been liberated after the expansion of the European Union into the Baltic countries. In the future, Finland's alcohol legislation may prove disadvantageous in contributing to an increase of firearm injuries in the country. Moreover, the unification of Europe can become a risk factor when considering the reported increase in the use of firearms in the other member states.

Summary

The occurrence and nature of civilian firearm- and explosion-injuries in Finland, and the nature of severe gunshot injuries of the extremities were described in seven original articles. The main data sources used were the National Hospital Discharge Register, the Cause-of-Death Register, and the Archive of Death Certificates at Statistics Finland. The present study was population based. Epidemiologic methods were used in six and clinical analyses in five papers. In these clinical studies, every original hospital record and death certificate was critically analyzed.

The trend of hospitalized firearm injuries has slightly declined in Finland from the late 1980s to the early 2000s. The occurrence decreased from 5.1 per 100 000 person-years in 1990 to 2.6 in 2003. The decline was found in the unintentional firearm injuries. A high incidence of unintentional injuries by firearms was characteristic of the country, while violence and homicides by firearms represented a minor problem. The incidence of fatal non-suicidal firearm injuries has been stable, 1.8 cases per 100 000 person-years. Suicides using firearms were eight times more common during the period studied. This is contrary to corresponding reports from many other countries. However, the use of alcohol and illegal drugs or substances was detected in as many as one-third of the injuries studied.

The median length of hospitalization was three days and it was significantly associated with the type of injury. The mean length of hospital stay has decreased from the 1980s to the early 2000s.

In this study, there was a special interest in gunshot injuries of the extremities. From a clinical point of view, the nature of severe extremital gunshot wounds, as well as the primary operative approach in their management, varied. The patients with severe injuries of this kind were managed at university and central hospital emergency departments, by general surgeons in smaller hospitals and by orthopaedic, plastic or vascular surgeons in larger hospitals. Injuries were rarities and as such challenges for surgeons on call. Some noteworthy aspects of the management were noticed and these should be focused on in the future. On the other hand, the small population density and the relatively large geographic area of Finland do not favor high volume, centralized trauma management systems. However, experimental war surgery has been increasingly taught in the country from the 1990s, and excellent results could be expected during the present decade.

Epidemiologically, explosion injuries can be considered a minor problem in Finland at present, but their significance should not be underestimated. Fatal explosion injuries showed up sporadically. An increase occurred from 2002 to 2004 for no obvius reason other than a bombing attack for unknown motives in 2002. However, in view of the historical facts, a possibility for another rare major explosion involving several people might become likely within the next decade.

The national control system of firearms is mainly based on the new legislations from 1998 and 2002. However, as shown in this study, there is no reason to assume that the national hospitalization policies, or the political climate, or the legislation might have changed over the study period and influenced the declining development, at least not directly. Indeed, the reason for the decline to appear in the incidence of unintentional injuries only remains unclear. It may derive from many practical steps, e.g. locked firearm cases, or from the stability of the community itself. For effective reduction of firearm-related injuries, preventive measures, such as education and counseling, should be targeted at recreational firearm users.

To sum up, this study showed that the often reported increasing trend in firearm as well as explosion-related injuries has not manifested in Finland. Consequently, it can be recognized that, overall, the Finnish legislation together with the various strategies have succeeded in preventing firearm- and explosion-related injuries in the country.

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Original publications